1.0 NATURE AND SCOPE OF BIOLOGICAL SCIENCE

1.1 The Science Biology

1.1.1 Definition of Biology

The word biology comes from the Greek words *bios*, which means *life*, and *logos*, which means *thought*. *Biology* is the science of life. *Biologists* study the structure, function, growth, origin, evolution and distribution of living organisms. An organism is a living entity consisting of one cell e.g. bacteria, or several cells e.g. animals, plants and fungi. Aspects of biological science range from the study of molecular mechanisms in cells, to the classification and behaviour of organisms, how species evolve and interaction between ecosystems.

1.1.2 Main Fields of Biology

Modern biology is vast science. Over 2,000,000 different kinds or species of organisms have been identified and new ones are still being discovered. They range in size and complexity from tiny bacteria to trees and humans. Because biology is such a large field, it is broken down into several subdivisions for easier study. These observations are formed according to the group of organisms being studied or the approach taken to the study of the organisms.

1.1.2.1 Group of Organisms Being Studied

Examples of some of the main fields of biology formed according to the group of organisms being studied:

Botany	The study of plants.
Zoology	The study of animals.
Microbiology	The study of microscopic organisms.
Bacteriology	The study of bacteria.
Virology	The study of viruses.
Mycology	The study of fungi.
Entomology	The study of insects.
Ornithology	The study of birds.

1.1.2.2 Approaches Taken to the Study of Organisms

Examples of some of the main fields of biology formed according to the approach taken to the study of the organisms:

Taxonomy	The classification of organisms.
Morphology	The study of the external form and structure of organisms.
Anatomy	The study of the internal structure of organisms.
Physiology	The study of the function of organisms.
Cytology	The study of cells.
Ecology	The study of the relationship of organisms to their environment.
Genetics	The study of inheritance
Pathology	The study of diseases.

1.1.3 A New Definition of Biology

Biology was first defined as the science that deals with the study of life. However, as we learn more, we see that biology involves many other things. It is also a study of all those things that affect life. Thus the following is a more accurate definition of biology: *Biology is the study of living things and the things that were once alive, together with the matter and energy that surround them.*

1.2 Characteristics of Living Things

1.2.1 What Is Life?

What is life? What is the difference between a living and a nonliving thing? You would have no trouble deciding that a dog running down the street was alive; nor would you have any trouble deciding that a stone was nonliving. However, if you ask yourself whether a bean seed, an apple, or a potato is living or nonliving, you may have problems deciding on the answer. All these appear just as nonliving as a stone. Yet we know that all three can produce a living plant. Since it seems unlikely that a nonliving thing can produce a living plant, we can assume that the bean seed, apple, and potato are living. *What, then, are the characteristics of living things?*

1.2.2 Characteristics of Living Things

There are nine characteristics of living things.

1. The need for energy
2. Movement
3. Cellular structure and organization
4. Growth and development
5. Maintenance and repair
6. Reproduction
7. Response to stimuli
8. Variation and adaptation
9. Metabolism

1.2.2.1 The Need for Energy

All living things require a continuous supply of energy to support their more obvious characteristics such as movement, growth, and reproduction. Almost all the energy used by living things comes originally from the sun (**Figure 1.1**). Green plants, through photosynthesis, store some of the sun's energy in compounds such as glucose. These plants, through respiration, then '*burn*' or breakdown the glucose, releasing the energy needed to support their life processes.

Animals get their supply of energy by eating the plants or by eating other animals that have eaten plants. By doing this, they obtain glucose and other compounds which they too, break down through respiration to release energy to support their life processes.

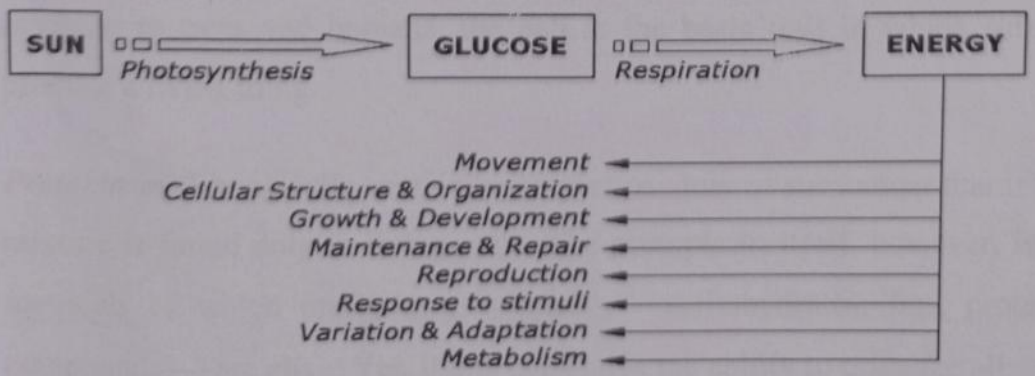


Figure 1.1: All living things have common characteristics. These characteristics are functions that require energy.

1.2.2.2 Movement

One of the most obvious characteristics of living things is movement. Most animals show obvious signs of movement when they are alive. Although movement in plants is not as obvious, it does occur. This movement can be very slow, such as (1) the opening of buds on a tree or (2) the turning of leaves of a plant toward the sun. In contrast, (3) the tiny sundew of northern bogs and (4) the Venus flytrap of Carolinian bogs show much more rapid motion. One of the most interesting examples of motion in plants is shown by (5) the *Mimosa pudica*, commonly called the sensitive plant. If this plant is touched, its leaves quickly fold up.

Many animals, plants, and microscopic organisms show few or no outward signs of movement. Yet under the microscope, you can see that the cell contents of these organisms are in continuous motion. This proves that in one way or another, all living things show movement.

Locomotion: Some organisms show a special type of movement called locomotion. Locomotion is the movement of an organism from one place to another. Most animals can carry out locomotion but very few plants can. Remember that both movement and locomotion, in a biological sense, must be initiated or caused by the organism itself. Locomotion does not occur when the wind blows a plant from one place to another, nor does movement occur when the wind moves the branches of a tree.

1.2.2.3 Cellular Structure and Organization

Cell: All living things are made up of *cells*. Some have only one cell; others have millions of cells. Some cells are very simple and others are very complex. However, from bacteria and amoebas to trees and humans, the cell is the basic unit in which substance are organized to produce a living thing.

Protoplasm: Living cells contain a complex mixture of substances that is called *protoplasm*. This mixture is found only in living cells. The protoplasm itself, however, is not alive. None of the materials of which protoplasm is made — carbohydrates, fats, proteins, waters, and other compounds — are alive. Yet, living cells have the ability to organize all these materials into what biologists call a *living condition*. Protoplasm differs from one kind of organism to another and even from one individual to another of the same kind. It even differs from one part of an

individual to another part of the same individual. In fact, the composition, or makeup, of any particular sample of protoplasm is always changing.

Organism: Living things have the ability to organize materials into protoplasm and to organize protoplasm and other substances into cells. Living things are therefore called *organisms* because of this ability to organize substances.

1.2.2.4 Growth and Development

Growth of Living Things: All living things grow at some time during their lives. The total growth may be very small, as in the case of a bacterium or an amoeba. Total growth can be quite extensive, as in the case of a whale or a large tree. Yet, whether great or small, growth is a characteristic of all living things.

Growth of Non-living Things: However, many nonliving things can also grow. For example, crystals of sugar, salt, and bluestone can be made to grow larger. You probably have seen an icicle grow. *How, then, can we say that growth is a characteristic of living thing? What kind of growth are we referring to?*

The crystals and the icicle grow larger by adding more material of the same kind to their surfaces. The growth of living things is quite different from this. A dog does not grow by the collection of more dogs on its surface; nor does a mango plant grow by the collection of more mango plants on its surface. Yet, neither of these organisms grows simply by taking in food. They must organize the food, along with water, minerals, and other chemicals, into the complex materials that make up protoplasm and the other parts of living cells.

Living things grow, not by adding more of their own material to their surfaces, but by organizing materials that they take in to form their own special kind of protoplasm.

Development: If you plant a bean seed, it will become a bean plant. It never becomes a potato plant or a tree. It becomes a unique living thing with specialized parts that make it different from other living things. The series of changes that take place as an organism grows toward its final form is called *development*. All living things undergo development.

1.2.2.5 Maintenance and Repair

Most living things live long after growth appears to have stopped. Yet, in one sense, they continue to grow as long as they are alive. They may not grow any larger but they must continually maintain and repair the materials of which they are made. For example: (1) Skin cells on your body wear away and must be replaced by new ones. A cut on your finger heals because new tissues are produced to cover the cut. (2) Some organisms, such as the salamander, house lizard and crayfish, can even grow new limbs or tail to replace lost ones by recognizing old, and adding new, material.

Living things use great deal of energy in the maintenance and repair of worn-out and damaged parts. This is a characteristic of all living things.

1.2.2.6 Reproduction

Reproduction: *Reproduction is the process whereby all living organisms produce offspring.* Only living things can produce offspring similar to themselves. (1) Shrimps lay eggs that hatch and develop into shrimps. (2) Bluebirds lay eggs that eventually produce bluebirds. (3) Horses give birth to horses. (4) Apple seeds grow into apple plants. (5) Mango seeds become mango trees. *It is a basic law of biology that only life can produce life and like produces like.*

Organisms must be able to reproduce themselves because they have a limited life span. After most organisms are formed, they go through a period of rapid growth. They eventually reach a stage called *maturity* at which growth in size usually ceases but maintenance and repair may continue. They then enter a period of *decline* in which maintenance and repair of worn-out and damage materials are no longer fast enough to keep the organisms in a stable state. Finally *death* occurs.

Life Span: *Life spans* vary considerably from one type of organism to another. (1) Some insects live only a few weeks. (2) A person in Western world can expect to live, on the average, about seventy years. (3) A horse lives about thirty years. (4) Some trees live for a few decades and *others* for hundreds of years. (5) Some redwood trees in California have lived for several thousand years. (6) Some simple organisms such as bacteria and amoebas appear to have an

indefinite life span. In a sense, they live forever, because they reproduce by splitting in two. The offspring repeat this process. Clearly such organisms never die of old age!

Organisms use a great deal of energy in the reproduction of offspring. This also is a characteristic of all living things.

1.2.2.7 Response to Stimuli

Irritability: All living things are able to respond to certain *stimuli* or change in their environment (surroundings). (1) A dog comes when you whistle. (2) A fly moves when you try to swat it. (3) A *Mimosa* (sensitive) plant folds its leaves in response to darkness, touch, and heat. (4) A plant in a window turns its leaves toward the light. (5) Earthworms seek out moist soil containing decaying vegetation.

In all these examples a *stimulus* — sound, touch, heat, light, moisture — causes a response by a living thing. A living thing's response to a stimulus is called *irritability*.

Irritability in Animals: Irritability is valuable to animals in many ways. It helps them obtain food and avoid predators. It is most highly developed in those animals that have *nervous systems* and keen *sense organs* such as eyes, nose, and ears.

Irritability in Plants: Plants usually respond slowly to *stimuli* because they lack sense organs, muscles, and other parts needed for a quick response. However, they usually respond to *light* by turning their leaves towards it. They also respond to *gravity* by sending roots downward into the soil.

Irritability in Microorganisms: Even single-celled organisms such as amoebas show *irritability*. Such organisms respond to *touch*, *light*, *heat*, and *other environmental stimuli*.

Coordination: Response to stimuli must be *coordinated* if they are to be effective. Even simple organisms have many parts and each part must do the right thing at the right time if the proper response is to be carried out. For example, when you call a dog to supper, stimuli will be received by one or more of the *eyes*, *ears*, and *nose*. The responses to these stimuli must be coordinated within the dog before it can respond properly. Some muscles must contract; others

must relax; digestive juices must be secreted. A system of nerves and a system of chemical regulators called *hormones* coordinates these responses in a dog and many other animals. In plants, only hormones are involved in the coordination of responses.

Behaviour: Organisms respond to stimuli by changing their relationship to it. For example, a dog usually comes when you whistle. It changes its location in response to the stimulus. Such responses, which often occur in definite pattern, are called *behaviour*. Remember that behaviour must begin with the organism. A ball rolling down a hill is not showing behaviour. It is simply being pulled along by the force of gravity. However, a dog that responds to a whistle creates a change in its relationship to its environment. Your whistle does not pull the dog to you. Organisms use a considerable amount of energy as they respond to stimuli within their environments.

1.2.2.8 Variation and Adaptation

Variation: *Change occurs as a result of a characteristic feature is called variation.* Offspring always differ in some ways from one another and from their parents. These differences are called *variations*. Most variations do not affect an organism's chances of survival. For example, the fact that your hair is a different colour from your parents will not likely affect your chances of survival.

Adaptation: *The process by which a certain type of organisms becomes better suited to survive in its environment is called adaptation.* Keep in mind that organisms do not change in order to survive in a changing environment. The deer in our example did not grow long legs because they needed them to survive in the deep snow.

Organisms do not change to survive; they survive because they change.

1.2.2.9 Metabolism

What is Metabolism: *Metabolism* is the exchange of matter and energy between an organism and its environment, and the changes that occur in this matter and energy when they are within the organism.

In effect, metabolism is the sum of all the processes occurring in an organism.

1. It includes taking in food, or *ingestion*, as well as taking in water and air.

2. It also includes all the changes in food materials that occur within organisms during *digestion*.
3. It includes all changes that occur as the products of digestion are *assimilated*, or put together, during growth, maintenance, and repair.
4. It includes the release of energy through *respiration*.
5. Finally, it includes the elimination of by-products through *excretion*.

Anabolism vs. Catabolism: Metabolism has two distinct phases, anabolism and catabolism.

1. *Anabolism:* Anabolism is a constructive or building-up phase; it includes assimilation, or building of protoplasm from simple compounds and elements that were obtained as a result of ingestion and digestion. It also includes the process of photosynthesis.
2. *Catabolism:* Catabolism is a destructive or breaking-down phase; it involves the release of energy by the breakdown of food materials through respiration.

2.0 CELL BIOLOGY

Cell biology is the study of cell structure and function, and it revolves around the concept that the cell is the fundamental unit of life. Focusing on the cell permits a detailed understanding of the tissues and organisms that cells compose. Some organisms have only one cell, while others are organized into cooperative groups with huge numbers of cells. On the whole, cell biology focuses on the structure and function of a cell, from the most general properties shared by all cells, to the unique, highly intricate functions particular to specialized cells.

Story of Cell Biology

The cell theory, or cell doctrine, states that all organisms are composed of similar units of organization, called cells. The concept was formally articulated in 1839 by Schleiden & Schwann and has remained as the foundation of modern biology. The idea predates other great paradigms of biology including Darwin's theory of evolution (1859), Mendel's laws of inheritance (1865), and the establishment of comparative biochemistry (1940).

First Cells Seen in Cork

While the invention of the telescope made the Cosmos accessible to human observation, the microscope opened up smaller worlds, showing what living forms were composed of. The cell

was first discovered and named by Robert Hooke in 1665. He remarked that it looked strangely similar to cellular or small rooms which monks inhabited, thus deriving the name. However what Hooke actually saw was the dead cell walls of plant cells (cork) as it appeared under the microscope. Hooke's description of these cells was published in *Micrographia*. The cell walls observed by Hooke gave no indication of the nucleus and other organelles found in most living cells. The first man to witness a live cell under a microscope was Anton van Leeuwenhoek, who in 1674 described the algae *Spirogyra.* Van Leeuwenhoek probably also saw bacteria.

Formulation of the Cell Theory

In 1838, Theodor Schwann and Matthias Schleiden were enjoying after-dinner coffee and talking about their studies on cells. It has been suggested that when Schwann heard Schleiden describe plant cells with nuclei, he was struck by the similarity of these plant cells to cells he had observed in animal tissues. The two scientists went immediately to Schwann's lab to look at his slides. Schwann published his book on animal and plant cells (Schwann 1839) the next year, a treatise devoid of acknowledgments of anyone else's contribution, including that of Schleiden (1838). He summarized his observations into three conclusions about cells:

1. The cell is the unit of structure, physiology, and organization in living things.
2. The cell retains a dual existence as a distinct entity and a building block in the construction of organisms.
3. Cells formed by free-cell formation, similar to the formation of crystals (spontaneous generation).

We know today that the first two tenets are correct, but the third is clearly wrong. The correct interpretation of cell formation by division was finally promoted by others and formally enunciated in Rudolph Virchow's powerful dictum, *Omnis cellula e cellula*,: "All cells only arise from pre-existing cells".

Modern Cell Theory

1. All known living things are made up of cells.
2. The cell is structural & functional unit of all living things.
3. All cells come from pre-existing cells by division (Spontaneous Generation does not occur).
4. Cells contain hereditary information which is passed from cell to cell during cell division.
5. All cells are basically the same in chemical composition.

6. All energy flow (metabolism & biochemistry) of life occurs within cells.

As with the rapid growth of molecular biology in the mid-20th century, cell biology research exploded in the 1950's. It became possible to maintain, grow, and manipulate cells outside of living organisms. The first continuous cell line to be so cultured was in 1951 by George Otto Gey and co-workers, derived from cervical cancer cells taken from Henrietta Lacks, who died from her cancer in 1951. The cell line, which was eventually referred to as HeLa cells, have been the watershed in studying cell biology in the way that the structure of DNA was the significant breakthrough of molecular biology.

In an avalanche of progress in the study of cells, the coming decade included the characterization of the minimal media requirements for cells and development of sterile cell culture techniques. It was also aided by the prior advances in electron microscopy, and later advances such as development of transfection methods, discovery of green fluorescent protein in jellyfish, and discovery of small interfering RNA (siRNA), among others.

A Timeline

1595 – Jansen credited with 1st compound microscope
1655 – Hooke described 'cells' in cork.
1674 – Leeuwenhoek discovered protozoa. He saw bacteria some 9 years later.
1833 – Brown described the cell nucleus in cells of the orchid.
1838 – Schleiden and Schwann proposed cell theory.
1840 – Albrecht von Roelliker realized that sperm cells and egg cells are also cells.
1856 – N. Pringsheim observed how a sperm cell penetrated an egg cell.
1858 – Rudolf Virchow (physician, pathologist and anthropologist) expounds his famous conclusion: *omnis cellula e cellula*, that is cells develop only from existing cells [cells come from pre-existing cells]
1857 – Kolliker described mitochondria.
1879 – Fleming described chromosome behaviour during mitosis.
1883 – Germ cells are haploid, chromosome theory of heredity.
1898 – Golgi described the Golgi apparatus.
1938 – Behrens used differential centrifugation to separate nuclei from cytoplasm.
1939 – Siemens produced the first commercial transmission electron microscope.
1952 – Gey and co-workers established a continuous human cell line.
1955 – Eagle systematically defined the nutritional needs of animal cells in culture.

1957 – Meselson, Stahl and Vinograd developed density gradient centrifugation in cesium chloride solutions for separating nucleic acids.
1965 – Ham introduced a defined serum-free medium. Cambridge Instruments produced the first commercial scanning electron microscope.
1976 – Sato and colleagues publish papers showing that different cell lines require different mixtures of hormones and growth factors in serum-free media.
1981 – Transgenic mice and fruit flies are produced. Mouse embryonic stem cell line established.
1995 – Tsien identifies mutant of GFP with enhanced spectral properties
1998 – Mice are cloned from somatic cells.
1999 – Hamilton and Baulcombe discover siRNA as part of post-transcriptional gene silencing (PTGS) in plants

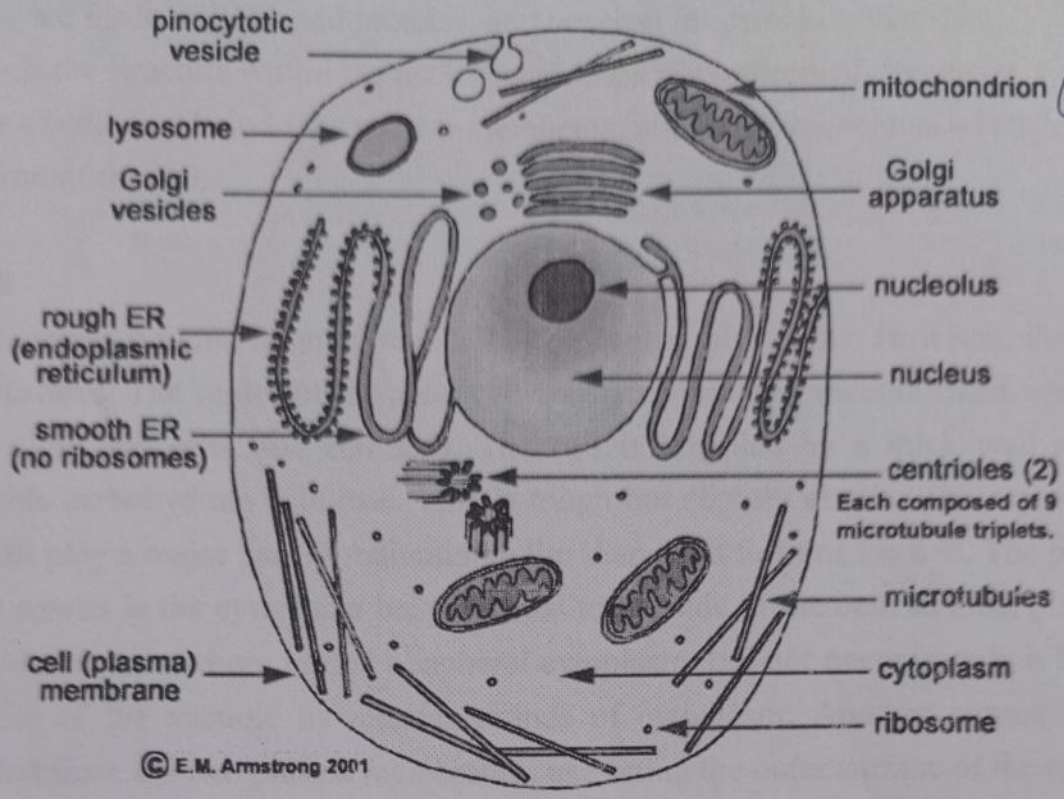
2.1 Animal Cell

All animal cells are multicellular. They are eukaryotic cells. Animal cells are surrounded by plasma membrane and it contains the nucleus and organelles that are membrane bound.

Animal cells are of various sizes and have irregular shapes. Most of the cells size range between 1 and 100 micrometers and are visible only with help of microscope. Trillions of cells are found in the human body. There are many different types of cells, approximately 210 distinct cell types in adult human body.

Animal Cell Definition

Animal cells are eukaryotic. Animal cells are having outer boundary known as the plasma membrane. The nucleus and the organelles of the cell are bound by a membrane. The genetic material (DNA) in animal cells is within the nucleus that is bound by a double membrane. The cell organelles have a vast range of functions to perform like hormone and enzyme production to providing energy for the cells.
The components of animal cells are centrioles, cilia and flagella, endoplasmic reticulum, golgi apparatus, lysosomes, microfilaments, microtubules, mitochondria, nucleus, peroxisomes, plasma membrane and ribosomes.



Animal cell

Parts of Animal Cell

Animal cell contains membrane bound nucleus, it also contains other membrane bound cellular organelles. These cellular organelles carry out specific functions that are necessary for the normal functioning of the cell. Animal cells lack cell wall, a large vacuole and plastids. Due to the lack of the cell wall, the shape and size of the animal cells are mostly irregular. The constituents of animal cells are structures like centrioles, cilia and flagella and lysosomes.

Parts of the animal cell are as follows:

Cell membrane - forms the outer covering of the cell, and is semi-permeable.

Cytoplasm - is a gel-like matrix where all the other cell organelles are suspended inside the cell.

Nucleus - contains the hereditary material DNA and directs the activities of the cell.

Centrioles - organize the microtubules assembly during cell division.

Endoplasmic Reticulum - are a network of membranes composed of rough and smooth endoplasmic reticulum.

Golgi complex - is responsible for storing, packaging of cellular products.

Lysosomes - are enzyme sacs, that digest cellular wastes.

Microtubules - are hollow rods, function primarily as support and shape to the cell.

Mitochondria - is the site for cellular respiration and producers of energy.

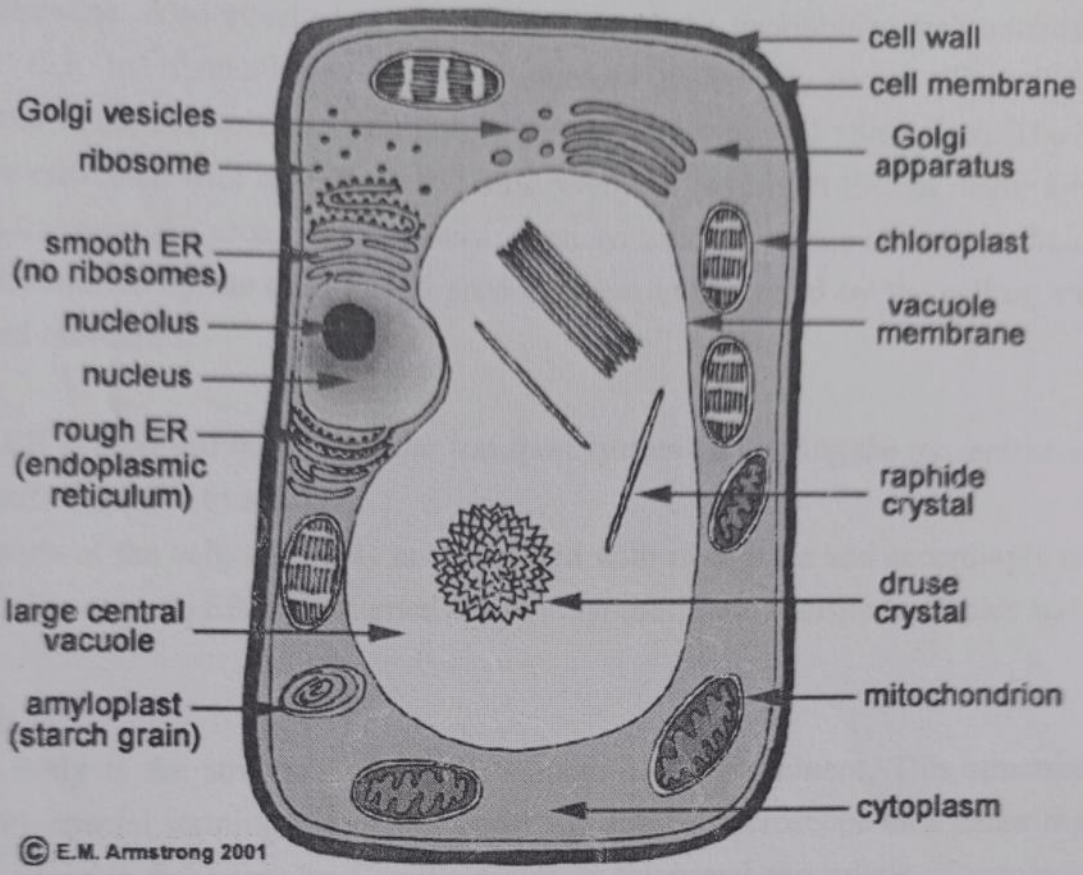
Ribosomes - are made of RNA and proteins, and are sites for protein synthesis.
Nucleolus - is the structure within the nucleus and helps in synthesis of ribosomes.
Nucleopore - is the tiny hole in the nuclear membrane, allows the movement of nucleic acids and proteins in/out of the cell.

A plant cell

Most of the structure found in an animal cell also occur in plant cells. However, there are some additional features. The center of the plant cell consists of a large vacuole filled with a solution containing sugar and salts (the cell sap). The cell is bounded by a thick wall made of the polysaccharide carbohydrate cellulose. This is tough but slightly elastic. The sap vacuoles and cellulose wall play a major part in maintaining the shape and form of the cell. The presence of a sap vacuole results in the cytoplasm being pushed to the side of the cell. In most plant cells, the nucleus is located somewhere in this peripheral cytoplasm, but not uncommonly it is suspended in the middle of the vacuole by slender strands of cytoplasm. Another consequence of the vacuole is that there are two plasma membranes, one lining the outer surface of the cytoplasm (in contact with the cellulose wall), and the outer lining the inner surface bordering the vacuole. The protoplasmic material sandwiched between these two membranes is referred to as the protoplast.

The cell wall which starts as a thin layer of calcium pectate beneath which cellulose, secreted by the outer layer of cytoplasm, is laid down is formed during the development of the cell. (This is the primary wall). Further cellulose constitutes the secondary wall. The point of demarcation between one cell and the next, is known as the middle lamella, and represents the fused pectate walls of the two adjoining cells. The cells even though they appear to be separate from each other are actually joined together by a narrow, pore carrying fine strands of cytoplasm. These are called **plasmodesma** strands or **plasmodesmata** and they facilitate movement of materials between cells. They also play the role of depositing cellulose during thickening of the secondary cell wall.

Granules and inclusions found in the cytoplasm include hollow ovoid or spherical bodies called plastids. Two main types are found. The leucoplasts which are colourless and contain starch; starch grains are found very widely in plant cells and represent the major form of storage carbohydrate, equivalent to glycogen in animal cells. The other type of plastid is the "chloroplast", which contains the green pigment "chlorophyll". The chlorophyll plays an important role in photosynthesis, which is the process by which plants manufacture food materials.



A plant cell as seen under the light microscope

Summary:

The features that are discussed here in both plants and animals are as seen in the light microscope. The only disadvantage of this type of microscope is that the rate of resolution of structures is very small when compared to the electron microscope. Some features are absent because they cannot be picked by the light microscope. However, the electron microscope usually gives higher resolution of structures thereby showing what is referred to as the fine structure of cells.

Fine structure of the cell

The organization in an individual cell as revealed by the electron microscope is known as its "fine structure, or ultra structure". The specific entities that make up this organization are called organelles. Infact, organelles stand in relation to the cell as organs do to the whole organism.

Endoplasmic Reticulum (ER)

The endoplasmic Reticulum is one of the most important structure found in the cytoplasm of an animal cell. It is a matrix containing a system of parallel flattened cavities lined with a thin membrane. The cavities are inter connected and the lining membranes are continuous with the

nuclear membrane. Also attached to the matrix side of the membranes are numerous granules which are rich in ribonucleic acid, and therefore called ribosomes. The ribosomes are manufactured in the nucleolus and are sites where protein synthesis takes place. The bulk of ER in a cell are encrusted with ribosomes and thus referred to as rough ER. Its major function is to isolate and transport the proteins which have been synthesized by the ribosomes. Some proteins that are not required by the cells which produce them are secreted by the cell eg are digestive enzymes and hormones.

The rough ER is involved in intracellular transport system facilitating the movement of materials from one part of the cell to another.
In certain parts of the cell, the ER is not encrusted with ribosomes and accordingly is known as smooth ER. The smooth ER is concerned with the synthesis and transport of lipids and steroids.

Golgi Body

The Golgi Body is the structure where the smooth ER is prominent. This structure could be detected with special staining techniques under the optical microscope as a dense region of the cytoplasm. Since it discovery by Camillo Golgi, it **triggered** the minds of cytologists. In the electron microscope it is seen to consist of stacks of flattened cavities lined with smooth ER close to which are numerous vesicles containing secretory granules. Because of it's association with secretory vesicles, it is said to be involved in the production of substances by the cell. Recent experiment has also proved that the golgi apparatus is an assembly point through which raw materials for secretion are funneled (sieved) before being shed from the cell

Mitochondria

Also found in the cytoplasm are variable number of mitochondria which appear as minute rods under the phase contrast and light microscope with dark-ground illumination. These structures become very apparent under the electron microscope. A typical cell is said to contain about a thousand mitochondria, though some cells have more than this figure. They vary in size and shape with generally sausage-shape. The wall of the mitochondrion consist of two thin membrane separated by an extremely narrow fluid-filled space. The inner membrane is highly folded giving rise to an irregular series of partitions, or Cristae, which project into the interior. The mitochondrion is one of the cell's most important organelles, because it is here that the chemical reactions of respiration take place, by which energy is generated for the needs of the cell. Generally speaking, the mitochondria is regarded as the power house of the cell. It is worthy to note that cells whose functions require a lot of energy usually have large numbers of

mitochondria. These are closely packed in such cells e.g. spermatozoa (at the base of the motile tail), contractile fibrils in muscle especially in the flight muscles of insects.

Lysosomes:

They are also present in the cytoplasm as dark spherical bodies. They contain potent enzymes responsible for splitting complex chemical compounds into simpler sub-units. They also destroy worn-out organelles within the cell. The unwanted structure may be worm out mitochondria or parts of the ER which are enveloped in a membrane which form a bag around them. In this bag are several lysosomes which discharge their contents bringing about the release of enzymes which break them down to form new organelles. Lysosomes sometimes may destroy the entire cell. In this case the lysosome membrane rupture and liberate its enzymes which digest the content of the cell, thereby killing the cell in this process. This may appear disastrous but beneficial in the parts where worn out cells are to be replaced by new ones. Lysosomes acts as suicide bags.

Plasma Membrane

The plasma membrane is made up of three layers: two dark layers, separated by a lighter region. The two dark layers have been known to consist of protein and the light region in between consists of lipid. Various materials pass through this membrane as they flow in and out of cells. The plasma membrane shares the same characteristics features as the membranes of other cell organelles like ER, sap vacuole, mitochondria. This kind of structure were ever it occurs, is known as the "unit membrane". Various structures are seen on the surface of the cell. Prominent amongst them are the micropinocytic vesicles, flask-like invaginations of the plasma membrane. The neck of the flask closes up so that the vesicle is sealed off from the outside and becomes entirely enclosed within the cell. These structures that are now known as vacuoles move freely in the cytoplasm.

Microvilli

These are minute hair-like process between 1.0um long and 0.80um wide. They are lined with plasma membrane and filled with cytoplasm which is continuous with the main body of the cell. They can only be seen with the aid of the electron microscope. The microvilli can only be found around the convoluted tubules in the kidney and the epithelial lining of the small intestine. They increase the surface area of the epithelium thereby aiding absorption of materials from the enclosed cavity.

Other organelles associated with the animal cell are the flagella, cilia and microtubules.

Fine Structure of Plant Cells

All the organelles found in animal cell also occur in plant cell. The only difference is that cilia, flagella and centrioles are confined to the more primitive plant groups such as algae and are absent in higher plants. However, plant cells possess certain additional features of their own, prominent amongst them are the chloroplast and the cell wall. A plant cell has a tin primary wall at the early stages of development composed of calcium pectate and some cellulose. However, with time more cellulose is laid down in a series of layers on the inner surface of the primary wall, giving rise to the thick secondary wall typical of a mature cell. In some cases, the secondary wall is absent altogether, giving rise to a pit.

3.0 PLANTS AND ANIMAL TISSUES

What is a Tissue?

A tissue is a cellular organizational level intermediate between cells and a complete organism. Hence a tissue is an assemblage of cells, not necessarily identical but from the same Origin, that together carry out a specific function. The study of tissues is called histology, or in connection with disease, histopathology.

Animal Tissue

In multicellular organisms, a group of similar cells with intercellular substances perform specific function; such an aggregation of cells is called tissue. Organs are functional group of many tissues. The study of tissue is known as histology. The study of tissues in connection with diseases of tissues is known as histopathology.

The word tissue is derived from a Latin word which means 'weave'. Cells that form tissues are woven together to form tissues. Tissues are sometimes held together by a sticky substance that coats the cells.

Animal Tissue Definition

Any distinct type of material animal cells is made of, which consists specialized cells and cellular products, which show inflammation reaction to any infection or injury are known as tissues. In animal organs are made up of four basic types of tissues epithelial tissue, connective tissue, muscle tissue and nerve tissue. These tissues have distinctive features and specific functions which combine to form functioning organs.

Four Types of Animal Tissue

Animal tissues are of four basic types: *Epithelial, Connective, Muscular* and *Neural tissues*. Multiple tissues compose organs and body structures. Generally animals are said to be made up of these basic four types of tissues, but the presence of these tissues may differ, depending on the type of organism. The origin of the cells of a type of tissues may differ in development stages in different classification of animals.

Animal Tissues and their Function

The structure of the cell varies according to its function. The tissues are different and are classified into four types:

- Epithelial tissue
- Connective tissue
- Muscular tissue and
- Neural tissue.

Epithelial Tissue

Epithelial tissue is commonly referred to as epithelium. The epithelial tissue forms the outer covering or lining for some part of the body. It is composed of closely packed cells, arranged in flat sheets. Epithelial tissues form the surface of the skin, lines many cavities of the body and cover the internal organs.

There are two types of epithelial tissues –simple epithelium and Compound Epithelium.

Simple epithelium is composed of single layer of cells. It functions as a lining of cavities of body, ducts and tubes.

compound epithelium *or stratified epithelium* is made of two or more cell layers. It functions as a protective covering, like it does in our skin.

Modifications of Simple Epithelium

- On the basis of structural modification the simple epithelium is divided into three types: *Squamous, Cuboidal, Columnar cells*.
- The squamous epithelium is made of a single layer of irregular, thin, flattened cells with irregular boundaries. They are found in the walls of blood vessels and in air sacs of lungs. They are involved in functions like forming a diffusion boundary.

- The cuboidal epithelium is made of a single layer of cube-like cells. They are commonly found in ducts of glands and tubules of nephrons. Its main functions are secretion and absorption.
- Columnar epithelium is composed of single layer of tall and slender cells. The free surface of these cells may have microvilli. They are found in lining of stomach and intestine. It helps in secretion and absorption.
- If the columnar epithelium bears cilia on their free surface they are called ciliated epithelium. They help to move particles or mucus in a specific direction. They are present in the inner surface of branchioles and fallopian tubes.

Compound Epithelium

It is made up of more than one layer of cells and has a limited role in secretion and absorption. They main function is to provide protection against stress. They cover dry surface of skin, moist surface of buccal cavity, pharynx and inner lining of salivary glands.

Connective Tissue

Connective tissues are the most abundant tissues of complex animals. They link and support other tissues/organs of the body. The connective tissues include cartilage, bone, adipose, and blood. All connective tissues except blood secrete structural proteins called collagen or elastin. Connective tissues are classified into three types - *Loose Connective tissue, Dense Connective tissue, and Specialized Connective tissue.*

Loose Connective tissue - These tissues have cells and fibres that are loosely arranged in a semi-fluid ground substance.

Areolar tissue - It is present beneath the skin, it serves as a framework support for epithelium. **Adipose tissue** - This type of tissues is specialized to store fats. Dense Connective tissue - Fibres and fibroblasts are packed compactly in dense connective tissue. Tendons are dense regular tissues that attach skeletal muscle to bones and ligaments attach bone to other bones. Collagen is the dense irregular tissue present in the skin.

Specialized connective tissue - Cartilage, bones and blood are types of specialized connective tissue.

Cartilage - Cartilage is solid, pliable tissue. The cells of this tissue are chondrocytes. Cartilage is present in the tip of the nose, outer ear joints, between bones of vertebral column.

Bones - They are hard and non-pliable, rich in calcium salts and collagen fibres. It provides structural frame to the bosy. The bone cells are osteocytes. The bone marrow in some bones is the site of production of blood cells.

Blood - It is a fluid connective tissue. It contains plasma, RBCs, WBCs and platelets.

Muscle Tissue

Muscle tissues are made of long cylindrical fibres, arranged in parallel arrays. These fibres are composed of fine fibrils known as myofibrils. The contraction and relaxation of moves the body to adjust to the changes in the environment. Muscles are of three types skeletal, smooth, and cardiac.

Skeletal Muscle - Skeletal muscle is also known as striated muscle. It is closely attached to the bones, example biceps.

Smooth Muscle- Smooth muscle fibres do not have striated. The wall of internal organs contains smooth muscles.

Cardiac Muscle- Cardiac muscle tissue is a tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac cells. Communication junctions allow the cells to contract as a unit.

Neural Tissue

Neural tissues control the body's responses to the changing conditions. Neurons are the units of neural system, they are excitable cells. The glial cells forms the rest of the neural system, they protect and support neurons. Its functions in receipt, processing and transferring information.

Structure of Animal Tissue

- *Epithelial tissues* cells are closely packed with junctions.
- *Simple cuboidal epithelium* is dice shaped cells.
- *Simple columnar epithelium* is large brick shaped cells.
- *Simple squamous epithelium* is single layer plate-like cells, thin and leaky.

- *Columnar epithelium* is single layer of cells, varying in height and ciliated in many vertebrates.
- *Loose connective tissue* gets its name from its loose weave of fibres.
- *Fibrous connective tissue* is dense with collagenous fibres.
- *Blood* has a liquid extracellular matrix called plasma, which consists of water, salts and dissolved proteins. The blood cells are suspended in the plasma.
- *Cartilage* contains collagenous fibres which are embedded in a rubbery protein-carbohydrate complex called chondroitin surface.
- *Bone* is a mineralized connective tissue, bone forming cells osteoblasts deposit collagen. Ions of calcium, magnesium and phosphate combine into a hard material within the matrix.
- *Smooth muscle* lack striations perform involuntary functions.
- *Cardiac muscle*s are striated. It is has fibres that interconnect via intercalated disks. Cells are uninuclear.
- *Muscle tissue* contains filaments containing proteins actin and myosin.
- *Nervous tissue*s are made of neurons and glial cells.

Plant Tissues

As for all animals, your body is made of four types of tissue: epidermal, muscle, nerve, and connective tissues. Plants, too, are built of tissues, but not surprisingly, their very different lifestyles derive from different kinds of tissues. All three types of plant cells are found in most plant tissues.

Three major types of plant tissues are dermal, ground, and vascular tissues.

Dermal Tissue

Dermal tissue covers the outside of a plant in a single layer of cells called the **epidermis**. You can think of the epidermis as the plant's skin. It mediates most of the interactions between a plant and its environment. Epidermal cells secrete a waxy substance called **cuticle**, which coats, waterproofs, and protects the above-ground parts of plants. Cuticle helps prevent water loss, abrasions, infections, and damage from toxins.

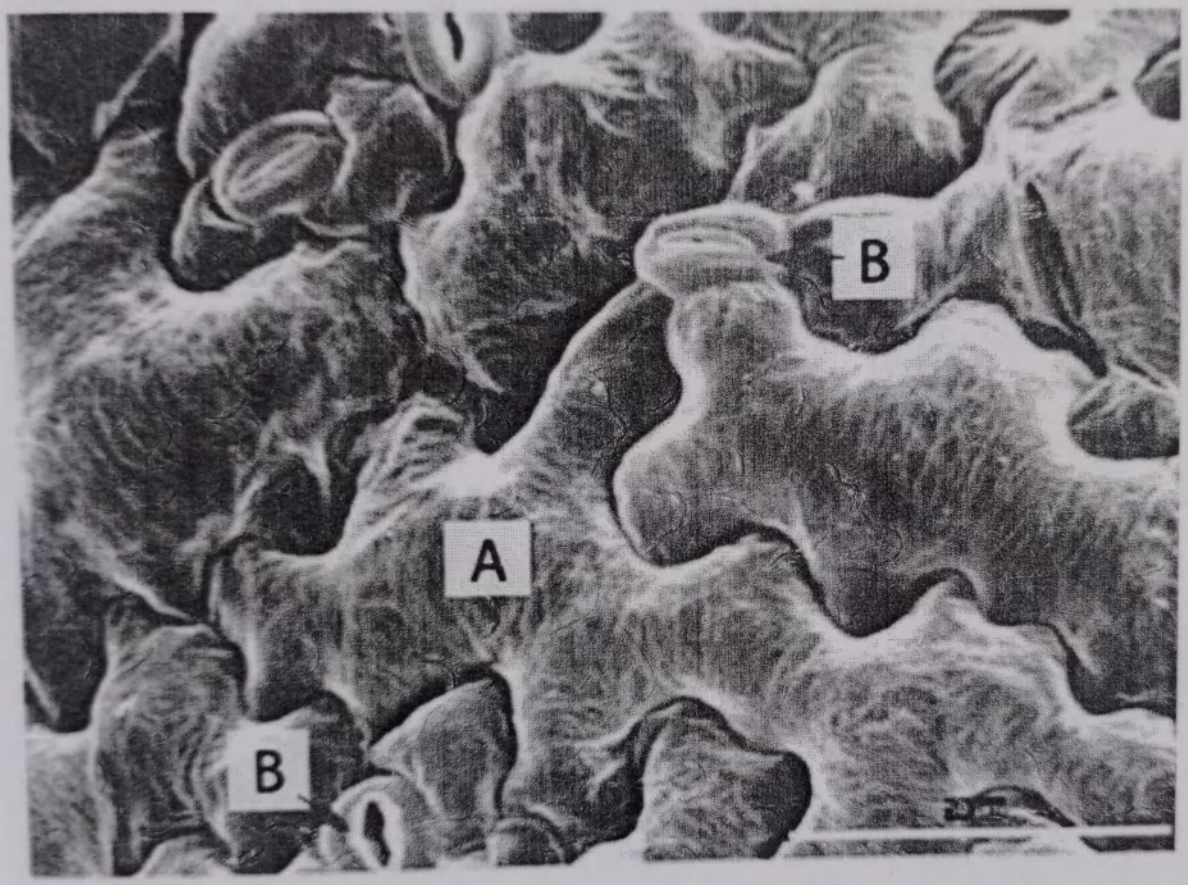
This tissue includes several types of specialized cells. Pavement cells, large, irregularly shaped parenchymal cells which lack chloroplasts, make up the majority of the epidermis. Within the epidermis, thousands of pairs of bean-shaped schlerenchymal **guard cells** swell and shrink by osmosis to open and close **stomata**, tiny pores which control the exchange of oxygen and carbon

dioxide gases and the release of water vapor. The lower surfaces of some leaves contain as many as 100,000 stomata per square centimeter.

Epidermis - the exchange of matter between the plant and the environment.

a) the epidermis on above ground organs (leaves and stems) is involved with gas exchange

b) the epidermis on below ground organs (roots) is involved with water and ion uptake



The epidermis of *Arabidopsis* shows both pavement cells (A) and stomata made of sclerenchymal **guard cells** (B), which control water loss and gas exchange.

Ground Tissue

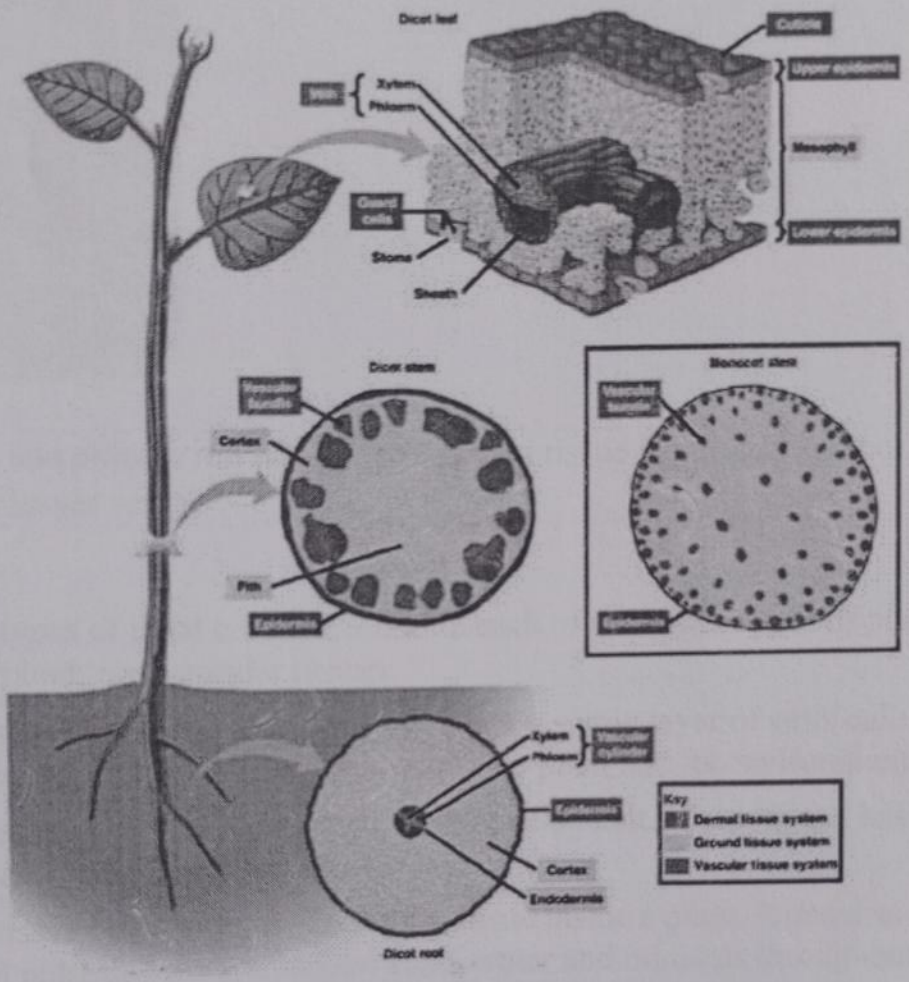
Ground tissue makes up much of the interior of a plant and carries out basic metabolic functions. Ground tissue in stems provides support and may store food or water. Ground tissues in roots may also store food.

Ground tissues - metabolism, storage, and support activities

a) the ground tissue of the leaf (called mesophyll) uses the energy in sunlight to synthesize sugars in a process known as photosynthesis

b) the ground tissue of the stem (called pith and cortex) develops support cells to hold the young plant upright

c) the ground tissue of the root (also called cortex) often stores energy- rich carbohydrates



The three tissue types of plants.

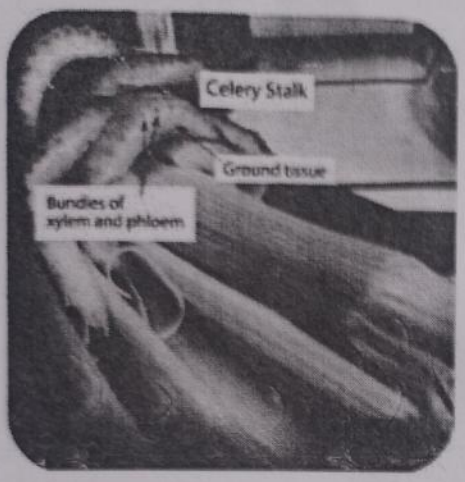
Vascular Tissue

Vascular tissue runs through the ground tissue inside a plant. Your body was able to grow from a single cell to perhaps 100 trillion cells because, 21 days after fertilization, a tiny heart began to pump blood throughout your tiny self – and it hasn't stopped since. The blood it pumps carries water, oxygen and nutrients to each one of your trillions of cells, and removes CO_2 and other wastes. Of course plants don't have hearts, but they do have vessels that transport water, minerals, and nutrients through the plant. These vessels are the vascular tissue, and consist of **xylem** and **phloem**. Xylem and phloem are packaged together in bundles, as shown in figure below.

Vascular tissues - the transport of water and dissolved substances inside the plant

a) the xylem carries water and dissolved ions from the roots to stems and leaves

b) the phloem carries dissolved sugars from the leaves to all other parts of the plant



Bundles of xylem and phloem run through the ground tissue inside this stalk of celery. What function do these tissues serve?

Summary

- The three types of plant cells are found in each of the major types of plant tissues: dermal, ground, and vascular tissues.
- Dermal tissue covers the outside of a plant in a single layer of cells called the epidermis. It mediates most of the interactions between a plant and its environment.
- Ground tissue makes up most of the interior of a plant. It carries out basic metabolic functions and stores food and water.
- Vascular tissue runs through the ground tissue inside a plant. It consists of bundles of xylem and phloem, which transport food, water and minerals throughout the plant.

4.0 CELL DIVISION

Cell division is the process by which a parent cell divides into two or more daughter *cells*

How do cells divide?

There are two types of cell division: mitosis and meiosis. Most of the time when people refer to "cell division," they mean mitosis, the process of making new body cells. Meiosis is the type of cell division that creates egg and sperm cells.

Mitosis is a fundamental process for life. During mitosis, a cell duplicates all of its contents, including its chromosomes, and splits to form two identical daughter cells. Because this process

is so critical, the steps of mitosis are carefully controlled by a number of genes. When mitosis is not regulated correctly, health problems such as cancer can result.

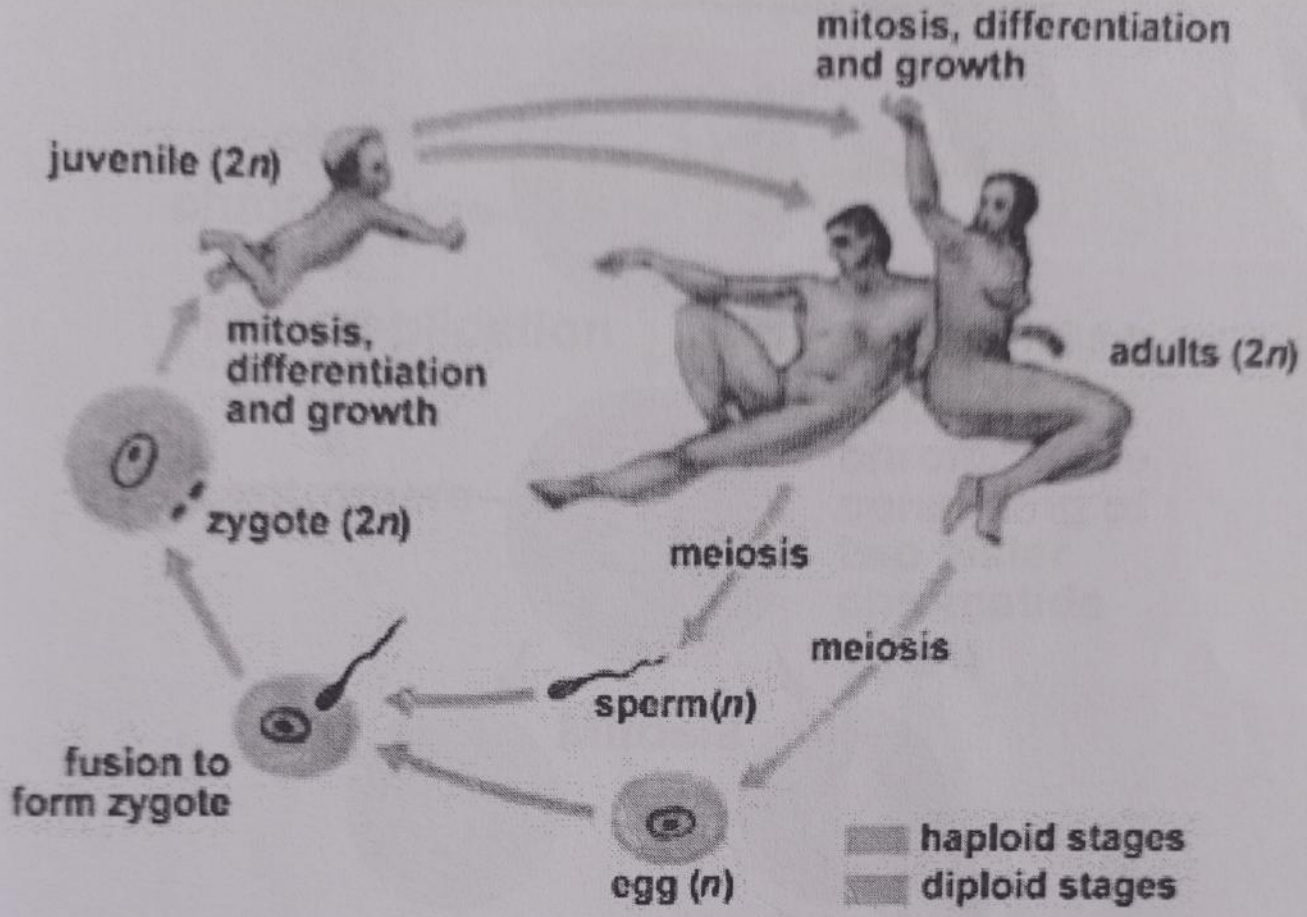
The other type of cell division, meiosis, ensures that humans have the same number of chromosomes in each generation. It is a two-step process that reduces the chromosome number by half—from 46 to 23—to form sperm and egg cells. When the sperm and egg cells unite at conception, each contributes 23 chromosomes so the resulting embryo will have the usual 46. Meiosis also allows genetic variation through a process of DNA shuffling while the cells are dividing.

Mitosis and meiosis, the two types of cell division.

4.1 MITOTIC CELL DIVISION

Definition: Mitosis is defined as *the type of cell division by which a single cell divides in such a way as to produce two genetically identical "daughter cells". This is the method by which the body produces new cells for both growth and repair of aging or damaged tissues throughout the body - as opposed to for sexual reproduction (when meiosis applies).*

Mitosis is the simplest of the two ways (mitosis and meiosis) in which the nucleus of a cell can divide - as part of a process of whole cell division. The four stages of mitosis (prophase, metaphase, anaphase and telophase) are illustrated and described below.



Mitosis Overview

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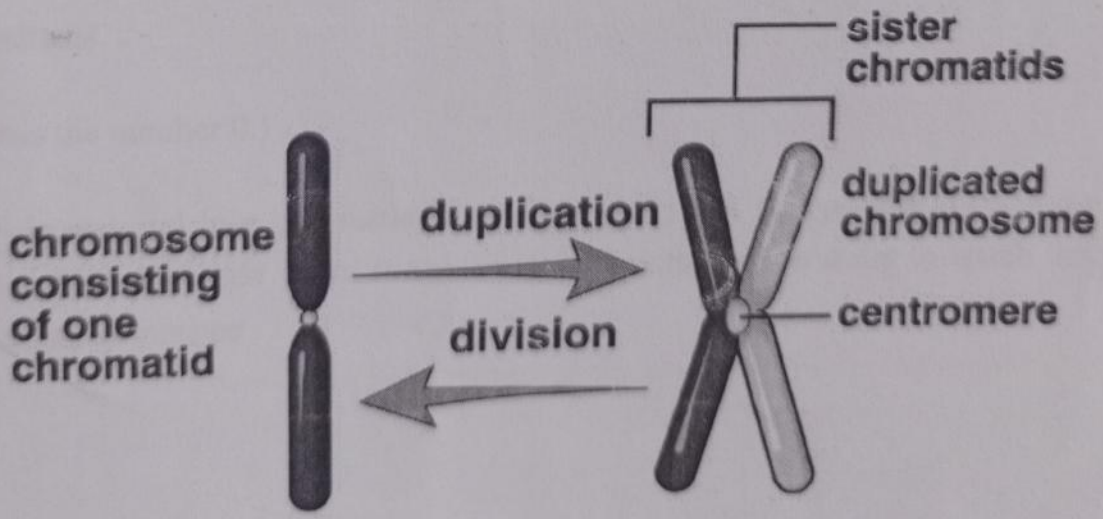

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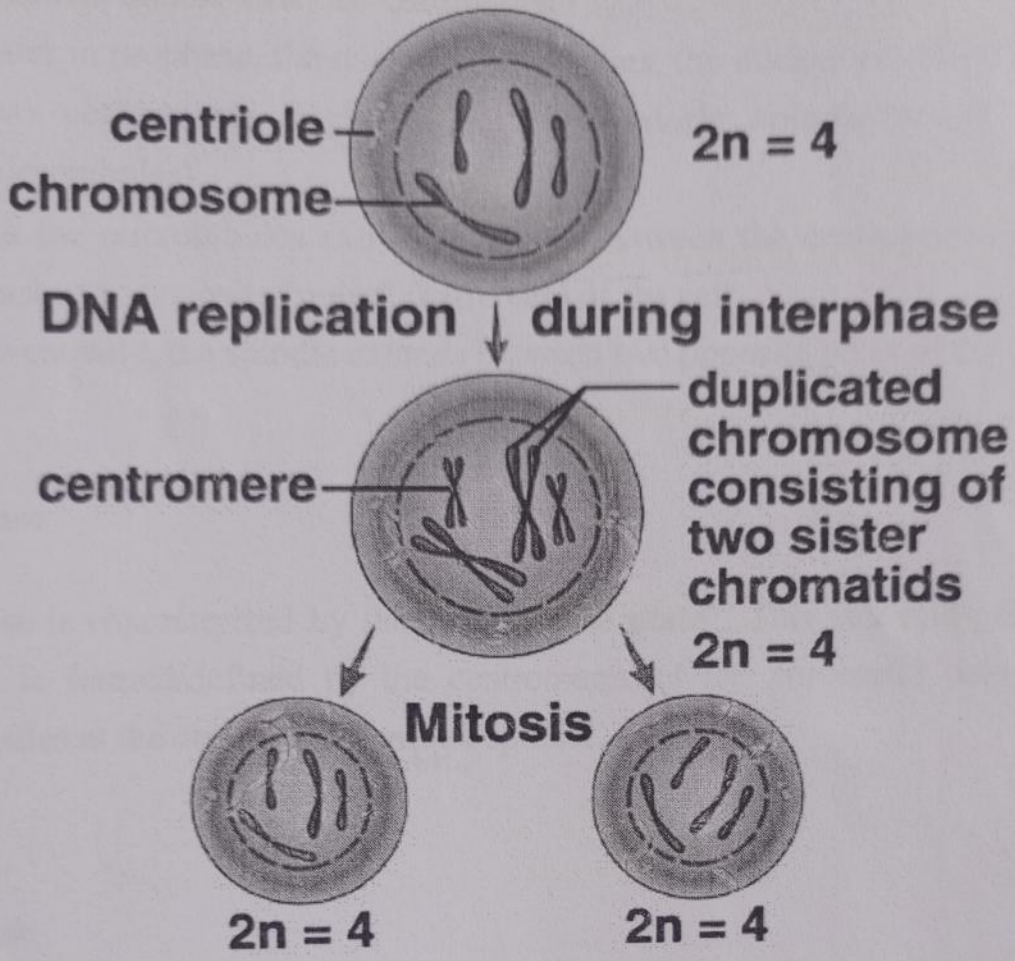


Mitosis (Nuclear Division)

Interphase: Interphase is not part of mitosis but is included here as a reminder that **interphase precedes mitosis.**

(Hence, it has the number 0.)

Chromatin is material in a cell nucleus consisting of DNA and protein. This is the substance that chromosomes are made from. It can be stained with dyes in order to watch the process of mitosis using a microscope

Prophase

- Early in the prophase stage the chromatin fibres shorten into chromosomes that are visible under a light microscope. (Each prophase chromosome consists of a pair of

identical double-stranded chromatids.)

- Later in prophase, the nucleolus disappears, the nuclear envelope breaks down, and the two centrosomes begin to form the **miotic spindle** (which is an assembly of microtubules).
- As the microtubules extend in length between the centrosomes, the centrosomes are pushed to opposite "poles" (extremes) of the cell.
- Eventually, the spindle extends between two opposite poles of the cell.

2. **Metaphase**

Metaphase is characterized by the "**metaphase plate**". This is a mid-point region within the cell that is formed/defined by the centromeres of the chromatid pairs aligning along the microtubules at the centre of the ~~miotic~~ mitotic spindle.

Anaphase

- The centromeres split separating the two members of each chromatid pair - which then move to the opposite poles of the cell: **When they are separated the chromatids are called chromosomes.**
- As the chromosomes are pulled by the microtubules during anaphase, they appear to be "V"-shaped because the centromeres lead the way, dragging the trailing arms of the chromosomes towards the pole/s.

4. **Telophase**

- Telophase begins after the chromosomal movement stops.
- The identical sets of chromosomes - which are by this stage at opposite poles of the cell, uncoil and revert to the long, thin, thread-like chromatin form.
- A new nuclear envelope forms around each chromatin mass.
- Nucleoli appear.
- Eventually the miotic spindle breaks-up.

Two new "daughter cells" - the cycle is about to repeat itself.

Interphase -

The cycle is about to start again ...

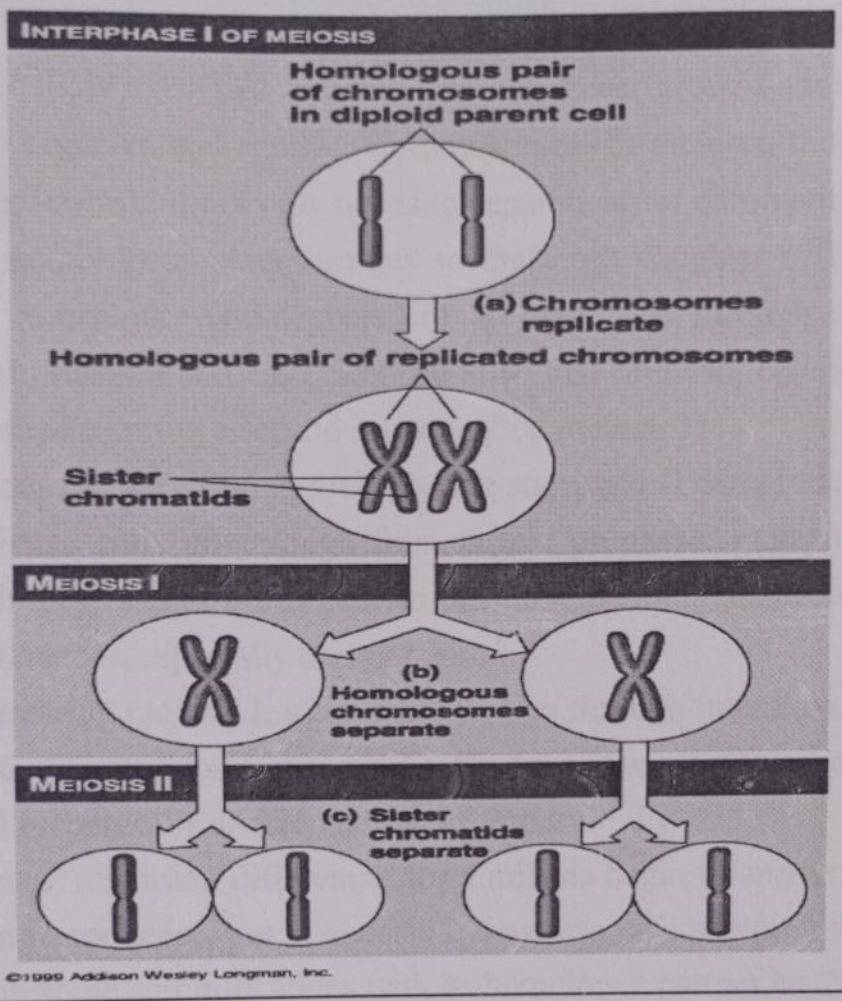
Interphase is not part of mitosis but is included here as a reminder that interphase precedes mitosis (Hence, it has the number 0) ... then the cytoplasm begins to divide around the two new nuclei - which is called **Cytokinesis (cytoplasmicDivision** When cytokinesis is complete, interphase begins (see further up this page). This begins the next "cell cycle".

4.2 MEIOTIC CELL DIVISION

The importance of meiosis

Proper segregation of chromosomes during meiosis I and II is essential Mitosis is used for almost all of your body's cell division needs. It adds new cells during development and replaces old and worn-out cells throughout your life. The goal of mitosis is to produce daughter cells that are genetically identical to their mothers, with not a single chromosome more or less. Meiosis, on the other hand, is used for just one purpose in the human body: the production of **gametes**—sex cells, or sperm and eggs. Its objective is not to create daughter cells that are identical to the starting cell, but rather to make daughters with exactly half as many chromosomes as the starting cell.

By definition, **meiosis** is a cell division process in which a diploid cell—one with two sets of chromosomes—gives rise to haploid cells—ones with a single set of chromosomes. In humans, the haploid cells produced by meiosis are sperm and eggs. When a sperm and an egg come together in fertilization, their two haploid sets of chromosomes combine to form a complete diploid set. This diploid set will be the genetic material, or genome, of a new individual.



Two Parts:

- **Meiosis I:**
  - Separation of **homologous pairs**
  - **Ploidy Level?**
- **Meiosis II:**
  - Separation of **sister chromatids**
  - **Ploidy Level?**

Phases of meiosis

In many ways, meiosis is a lot like mitosis. The cell goes through similar stages and uses similar strategies to organize and separate chromosomes. In meiosis, though, the cell has to pull off a more complex task. It not only needs to separate sister chromatids, as in mitosis, but must also separate homologous chromosomes so that each daughter cell gets just one from each pair, making it haploid. These goals are accomplished through a two-step division process. Homologues separate during a first round of cell division, called **meiosis I**, and the sister chromatids separate during a second round, called **meiosis II**.

Since cell division occurs twice during meiosis, one starting cell can produce four gametes. In each round of division, cells go through four stages: prophase, metaphase, anaphase, and telophase. Although these stages are similar to the corresponding stages of mitosis, there are some important differences, especially during meiosis I.

Meiosis I: Before entering meiosis I, a cell must first go through interphase. As in mitosis, the cell grows during G_11start subscript, 1, end subscript phase, copies all of its chromosomes during S phase, and prepares for division during G_2phase.

Prophase I: However, important differences from mitosis begin to appear. As in mitosis, the chromosomes begin to condense, but in meiosis I, they also do something unique: they start to pair up. Each chromosome carefully aligns with its homologue partner so that a particular gene on one homologue lines up with the matching gene on the other. For instance, in the image below, the letters A, B, and C represent genes found at particular spots on the chromosome, with capital and lowercase letters indicating different forms, or alleles, of each gene. Specialized proteins then break the DNA at the same spot on each homologue—for example, between genes B and C—and other proteins reconnect the DNA in a criss-cross pattern so that the homologues exchange a specific portion of their DNA.

This process, in which homologous chromosomes exchange corresponding parts, is called **crossing over**. It's helped along by a zipper-like protein structure called the **synaptonemal complex** that holds the homologues tightly together. The chromosomes would actually be positioned one on top of the other—as in the image to the right—throughout crossing over; they're only shown side-by-side in the image below so that it's easier to see the exchange of genetic material. You can see crossovers under a microscope as **chiasmata**, cross-shaped structures where homologues are linked together. Because the sister chromatids of each chromosome are connected along their length by **cohesins**, proteins that act as a kind of glue, chiasmata keep the homologues connected to each other after the synaptonemal complex breaks down. There's usually at least one crossover event per homologue pair, and it's common for multiple crossovers to take place. The X and Y chromosomes of a human male

are not true homologues, but they have small homologous, or matching, regions near their tips, which allow them to pair up and undergo crossing over, within those regions only.

The phases of meiosis I.

Prophase I: The starting cell is diploid, 2n = 4. Homologous chromosomes pair up and exchange fragments in the process of crossing over.

Metaphase I: Homologue pairs line up at the metaphase plate.

Anaphase I: Homologues separate to opposite ends of the cell. Sister chromatids stay together.

Telophase

After crossing over is complete, spindle microtubules begin to capture chromosomes and move them towards the metaphase plate. This process may sound familiar from mitosis, but once again, there is a twist in meiosis I. Now, each chromosome attaches to microtubules from just one pole of the spindle, and the two homologues of a pair are captured by microtubules from opposite poles. Thus, during **metaphase I**, homologue pairs—rather than individual chromosomes—line up at the metaphase plate, under tension from opposite spindle poles.

In **anaphase I**, the cohesin proteins covering the arms of sister chromatids are destroyed. This step breaks the chiasmata, allowing the homologues to move apart to opposite ends of the cell. Importantly, the cohesin proteins at the centromere are not destroyed, so the sister chromatids of each homologue remain attached to one another.

Finally, in **telophase I**, the chromosomes arrive at opposite poles of the cell. In some organisms, the nuclear membrane re-forms and the chromosomes decondense, although in others, this step is skipped—since cells will soon go through another round of division, meiosis II. Cytokinesis usually occurs at the same time as telophase I, forming two haploid daughter cells. The chromosomes in these cells still have two sister chromatids each, but the chromatids are no longer identical due to crossing over.

Meiosis II

Cells move from meiosis I to meiosis II without replicating their DNA. Meiosis II is a shorter and simpler process than meiosis I, and you may find it helpful to think of meiosis II as "mitosis for haploid cells", although mitosis itself can take place in haploid cells as well, depending on the organism.

The cells that enter meiosis II are the products of meiosis I. Both of these cells are haploid—they have one chromosome from each homologue pair—but their chromosomes still consist of two sister chromatids. In meiosis II, the sister chromatids separate, producing four haploid cells whose chromosomes have just one chromatid ea

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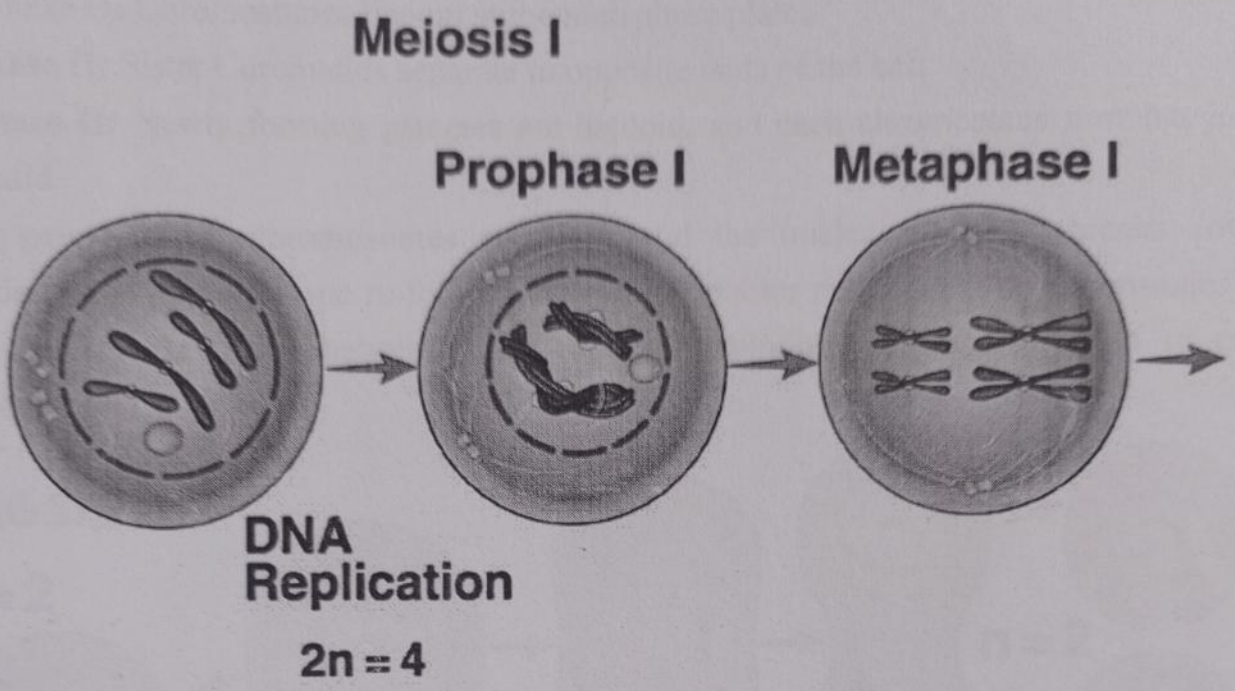

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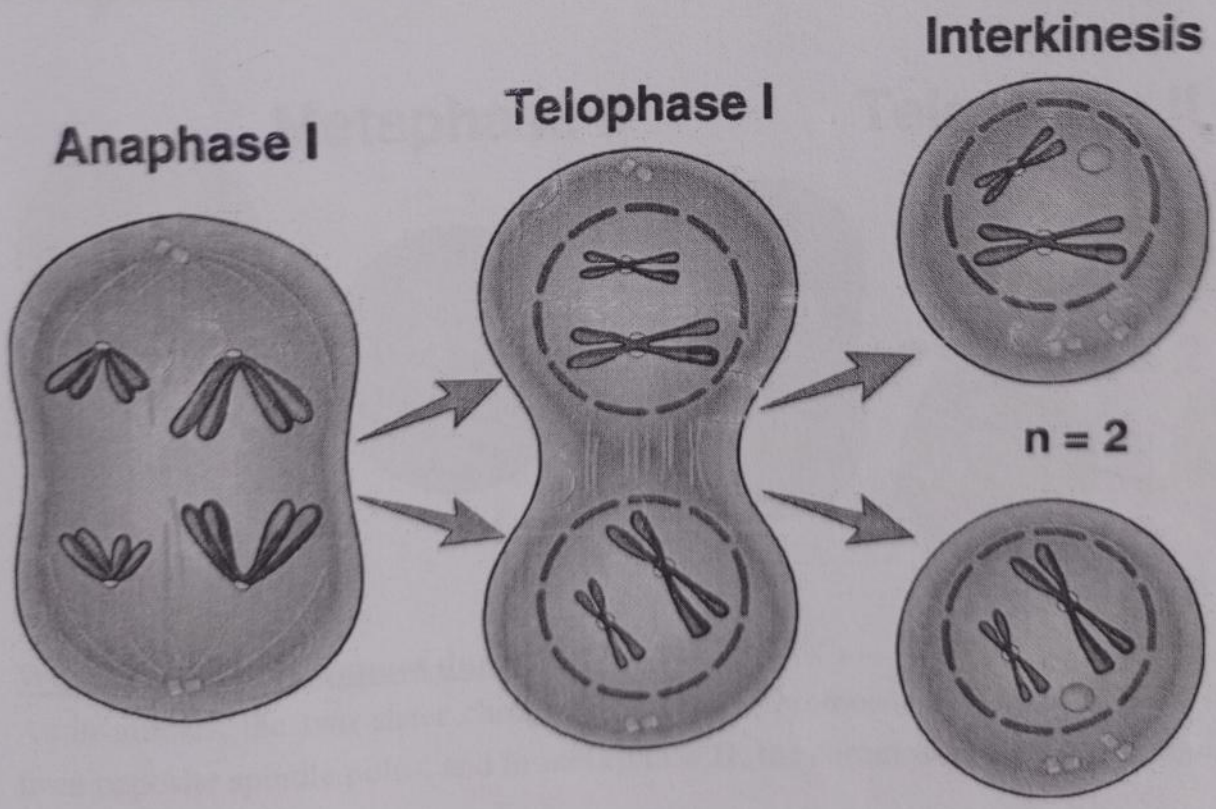


Phases of meiosis II

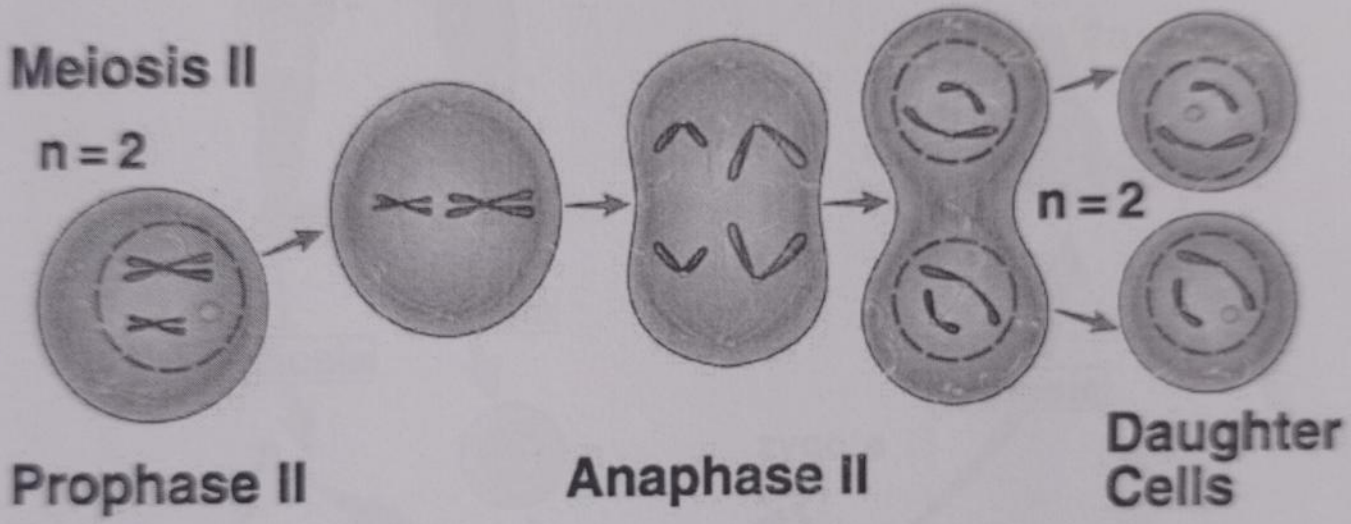
Prophase II: Starting cells are the haploid cells made in meiosis I. Chromosomes condense.

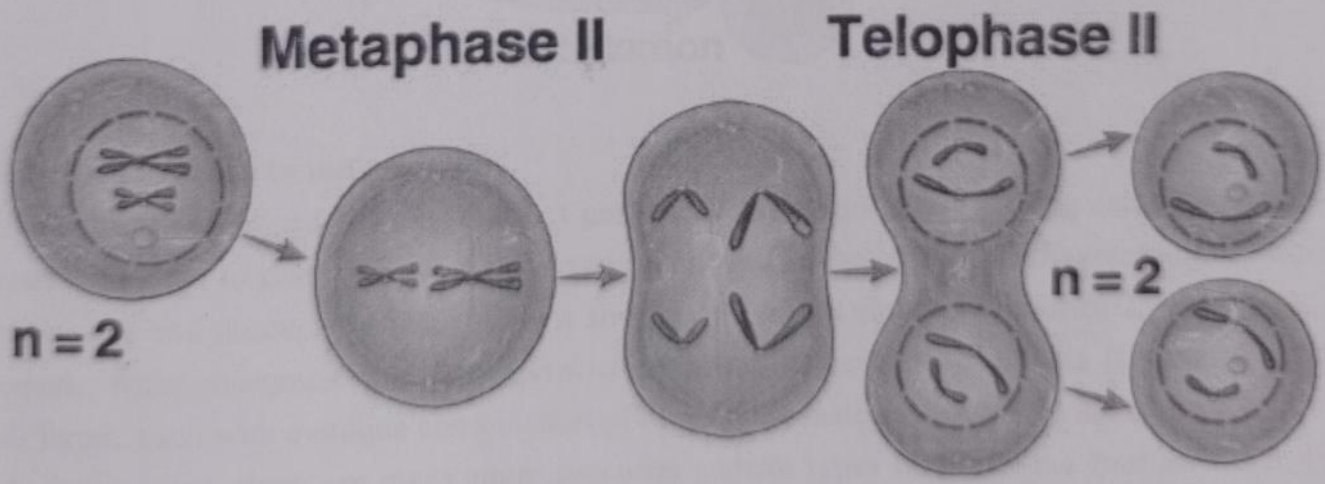
Metaphase II: Chromosomes line up at the metaphase plate.

Anaphase II: Sister Chromatids separate to opposite ends of the cell.

Telophase II: Newly forming gametes are haploid, and each chromosome now has just one chromatid.

During **prophase II**, chromosomes condense and the nuclear envelope breaks down, if decondensation and envelope re-formation took place after meiosis I. The centrosomes move apart, the spindle forms between them, and the spindle microtubules begin to capture chromosomes.





When did the centrosomes duplicate?

As in mitosis, the two sister chromatids of each chromosome are captured by microtubules from opposite spindle poles, and in **metaphase II**, the chromosomes line up individually along the metaphase plate.

Anaphase II commences when the cohesin proteins that hold the chromatids together, now found only at the centromere of each chromosome, are destroyed. The destruction of cohesin lets the sister chromatids separate towards opposite poles of the cell.

Finally, during **telophase II**, nuclear membranes re-form around each set of chromosomes, and the chromosomes decondense. Cytokinesis partitions the chromosome sets into new cells, forming the final products of meiosis: four haploid cells in which each chromosome has just one chromatid. In humans, the products of meiosis are sperm or egg cells.

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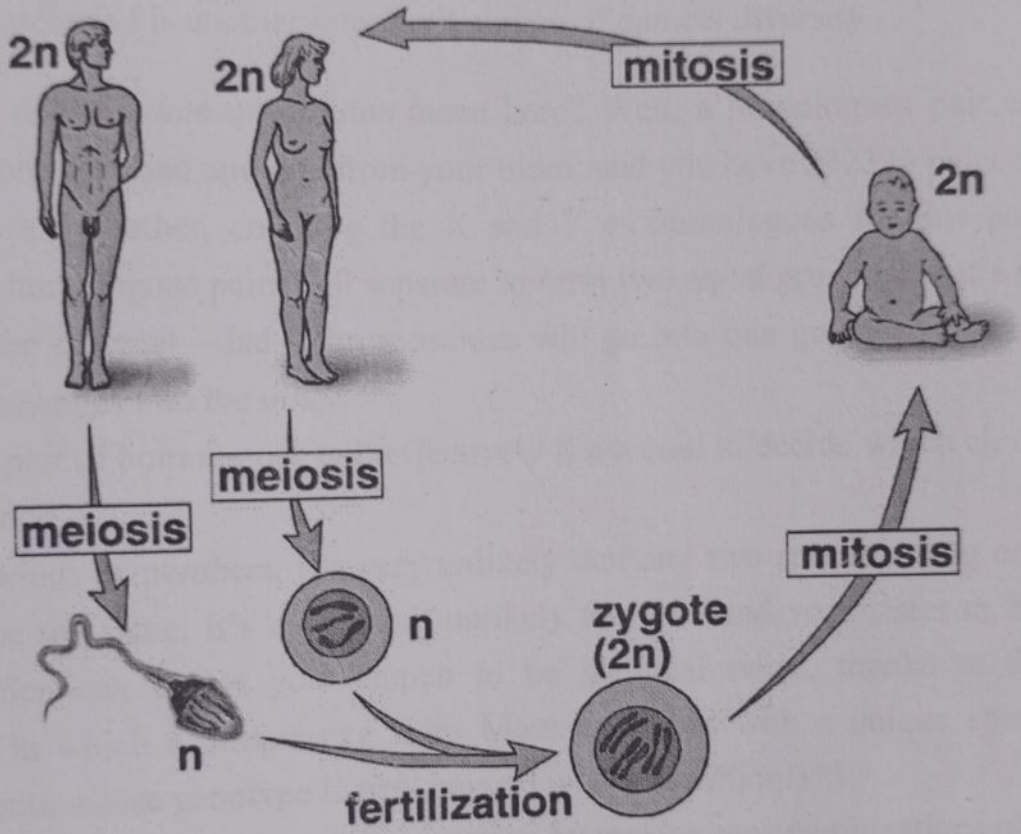

Genetic variation in meiosis

The gametes produced in meiosis aren't genetically identical to the starting cell, and they also aren't identical to one another. As an example, consider the meiosis II diagram above, which shows the end products of meiosis for a simple cell with a diploid number of 2n = 42*n*=42, n, equals, 4 chromosomes. The four gametes produced at the end of meiosis II are all slightly different, each with a unique combination of the genetic material present in the starting cell. As it turns out, there are many more potential gamete types than just the four shown in the diagram, even for a simple cell with only four chromosomes. This diversity of possible gametes reflects two factors: crossing over and the random orientation of homologue pairs during metaphase of meiosis I.

Crossing over. The points where homologues cross over and exchange genetic material are chosen more or less at random, and they will be different in each cell that goes through meiosis. If meiosis happens many times, as it does in human ovaries and testes, crossovers will happen at many different points. This repetition produces a wide variety of **recombinant** chromosomes, chromosomes where fragments of DNA have been exchanged between homologues.

Random orientation of homologue pairs. The random orientation of homologue pairs during metaphase of meiosis I is another important source of gamete diversity.

What exactly does *random orientation* mean here? Well, a homologous pair consists of one homologue from your dad and one from your mom, and you have 232323 pairs of homologous chromosomes all together, counting the X and Y as homologous for this purpose. During meiosis I, the homologous pairs will separate to form two equal groups, but it's not usually the case that all the paternal—dad—chromosomes will go into one group and all the maternal—mom—chromosomes into the other.

Instead, each pair of homologues will effectively flip a coin to decide which chromosome goes into which group.

Given those kinds of numbers, it's very unlikely that any two sperm or egg cells made by a person will be the same. It's even more unlikely that you and your sister or brother will be genetically identical, unless you happen to be identical twins, thanks to the process of fertilization (in which a unique egg from Mom combines with a unique sperm from Dad, making a zygote whose genotype is well beyond one-in-a-trillion!)^3

Meiosis and fertilization create genetic variation by making new combinations of gene variants (alleles). In some cases, these new combinations may make an organism more or less fit (able to survive and reproduce), thus providing the raw material for natural selection. Genetic variation is important in allowing a population to adapt via natural selection and thus survive in the long term.

COMPARISONS OF MITOSIS AND MEIOSIS

Cells divide and reproduce in two ways, mitosis and meiosis. Mitosis results in two identical daughter cells, whereas meiosis results in four sex cells. Below we highlight the keys differences and similarities between the two types of cell division.

Mitosis:

- Occurs in somatic (body) cells
- Growth, development, replacement & repair
- Produces 2 daughter cells
  - ► Clones of parent and each other
- Daughter cells are **diploid (2N)**

► Meiosis:

- Occurs in germ cells (immature reproductive cells)
- Production of **gametes** (sex cells)
- Produce 4 daughter cells
  - ► Distinct from parent and each other
- Daughter cells are **haploid (1N)**

5.0 MOLECULAR BIOLOGY

What is Molecular Biology?

Molecular biology is a branch of science concerning biological activity at the molecular level.

The field of molecular biology overlaps with biology and chemistry and in particular, genetics and biochemistry. A key area of molecular biology concerns understanding how various cellular systems interact in terms of the way DNA, RNA and protein synthesis function.

The specific techniques used in molecular biology are native to the field but may also be combined with methods and concepts concerning genetics and biochemistry, so there is no big distinction made between these disciplines.

However, when the fields are considered independently of each other, biochemistry concerns chemical materials and essential processes that take place in living organisms. The role, function and structure of biomolecules are key areas of focus among biochemists, as is the chemistry behind biological functions and the production of biomolecules.

Genetics is concerned with the effects of genes on living organisms, which are often examined through "knock-out" studies, where animal models are designed so that they lack one or more genes compared to a "wild type" or regular phenotype.

Molecular biology looks at the molecular mechanisms behind processes such as replication, transcription, translation and cell function. One way to describe the basis of molecular biology is to say it concerns understanding how genes are transcribed into RNA and how RNA is then translated into protein. However, this simplified picture is currently be reconsidered and revised due to new discoveries concerning the roles of RNA.

DNA: The genetic material

The physical nature of the gene fascinated scientists for many years. A series of experiments beginning in the 1920s finally revealed that DNA was the genetic material.

Discovery of transformation

A puzzling observation was made by Frederick Griffith in the course of experiments on the bacterium *Streptococcus pneumoniae* in 1928. This bacterium, which causes pneumonia in humans, is normally lethal in mice. However, different strains of this bacterial species have evolved that differ in virulence (in the ability to cause disease or death). In his experiments, Griffith used two strains that are distinguishable by the appearance of their colonies when grown in laboratory cultures. In one strain, a normal virulent type, the cells are enclosed in a polysaccharide capsule, giving colonies a smooth appearance; hence, this strain is labelled *S*. In Griffith's other strain, a mutant non-virulent type that grows in mice but is not lethal, the polysaccharide coat is absent, giving colonies a rough appearance; this strain is called *R*.

Griffith killed some virulent cells by boiling them and injected the heat-killed cells into mice. The mice survived, showing that the carcasses of the cells do not cause death. However, mice injected with a mixture of heat-killed virulent cells and live non-virulent cells did die. Furthermore, live cells could be recovered from the dead mice; these cells gave smooth colonies and were virulent on subsequent injection. Somehow, the cell debris of the boiled S

cells had converted the live R cells into live S cells. The process is called transformation. Griffith's experiment is summarized in Figure 8-1.

Figure 1

The first demonstration of bacterial transformation; (a) Mouse dies after injection with the virulent S strain. (b) Mouse survives after injection with the R strain. (c) Mouse survives after injection with heat-killed S strain. (d) Mouse dies after injection.

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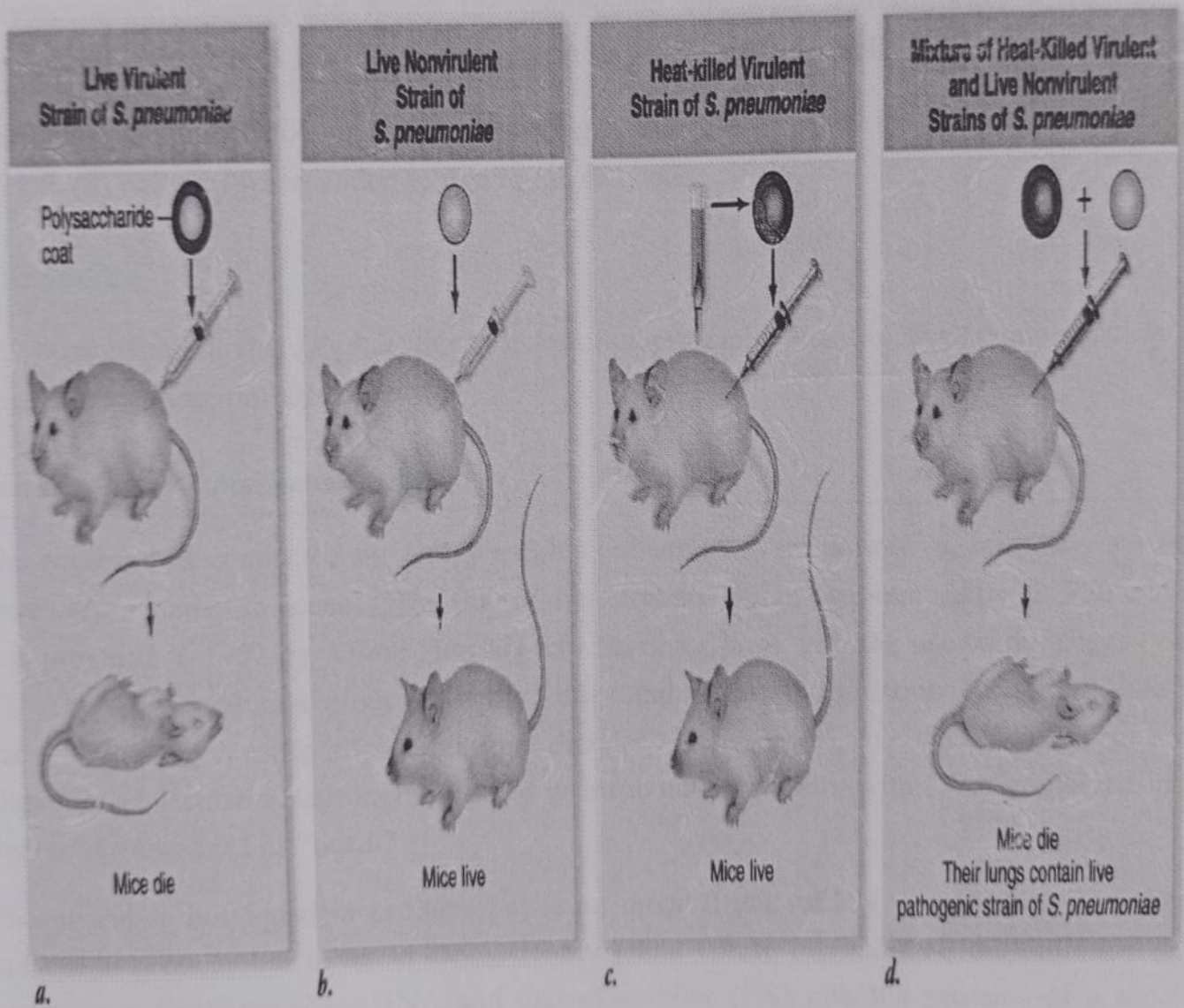

This same basic technique was then used to determine the nature of the *transforming principle*—the agent in the cell debris that is specifically responsible for transformation. In 1944, Oswald Avery, C. M. MacLeod, and M. McCarty separated the classes of molecules found in the debris of the dead S cells and tested them for transforming ability, one at a time. These tests showed that the polysaccharides themselves do not transform the rough cells. Therefore, the polysaccharide coat, although undoubtedly concerned with the pathogenic reaction, is only the phenotypic expression of virulence. In screening the different groups, Avery and his colleagues found that only one class of molecules, DNA, induced the transformation of R cells. They deduced that DNA is the agent that determines the polysaccharide character and hence the pathogenic character. Furthermore, it seemed that providing R cells with S DNA was tantamount to providing these cells with S genes.

Demonstration that DNA is the transforming agent. DNA is the only agent that produces smooth (S) colonies when added to live rough (R) cells.

MESSAGE

The demonstration that DNA is the transforming principle was the first demonstration that genes are composed of DNA.

Hershey-Chase experiment

The experiments conducted by Avery and his colleagues were definitive, but many scientists were very reluctant to accept DNA (rather than proteins) as the genetic material. The clincher was provided in 1952 by Alfred Hershey and Martha Chase with the use of the phage (virus) T2. They reasoned that phage infection must entail the introduction (injection) into the bacterium of the specific information that dictates viral reproduction. The phage is relatively simple in molecular constitution. Most of its structure is protein, with DNA contained inside the protein sheath of its "head."

Phosphorus is not found in proteins but is an integral part of DNA; conversely, sulphur is present in proteins but never in DNA. Hershey and Chase incorporated the radioisotope of phosphorus (^{32}P) into phage DNA and that of sulphur (^{35}S) into the proteins of a separate phage culture. They then used each phage culture independently to infect *E. coli* with many virus particles per cell. After sufficient time for injection to take place, they sheared the empty phage carcasses (called *ghosts*) off the bacterial cells by agitation in a kitchen blender. They used centrifugation to separate the bacterial cells from the phage ghosts and then measured the

radioactivity in the two fractions. When the ^{32}P-labeled phages were used, most of the radioactivity ended up inside the bacterial cells, indicating that the phage DNA entered the cells. ^{32}P can also be recovered from phage progeny. When the ^{35}S-labeled phages were used, most of the radioactive material ended up in the phage ghosts, indicating that the phage protein never entered the bacterial cell . The conclusion is inescapable: DNA is the hereditary material; the phage proteins are mere structural packaging that is discarded after delivering the viral DNA to the bacterial cell.

Figure 2

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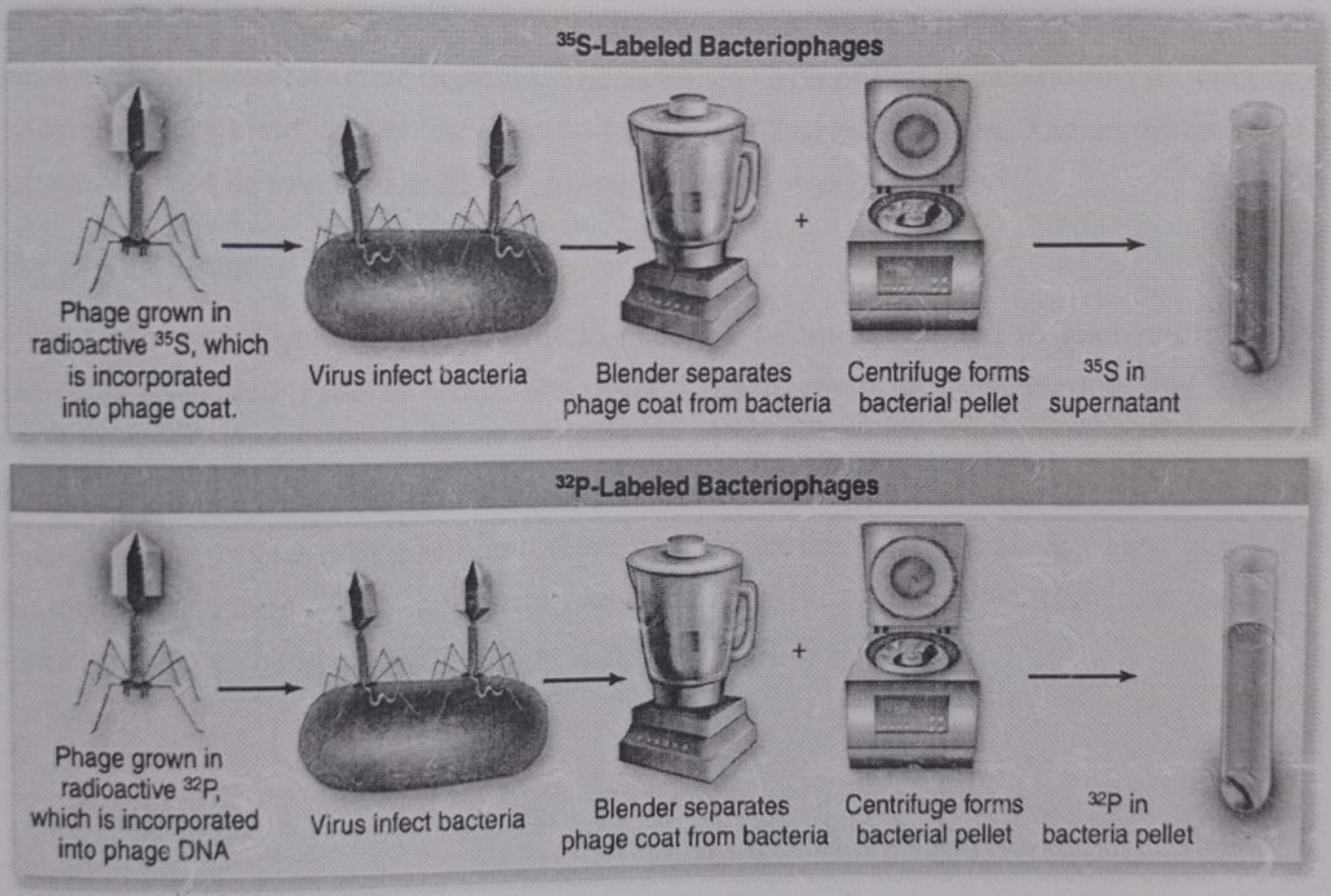

35S-Labeled Bacteriophages
Phage grown in radioactive 35S, which is incorporated into phage coat.
Virus infect bacteria
Blender separates phage coat from bacteria
+
Centrifuge forms bacterial pellet
35S in supernatant
32P-Labeled Bacteriophages
Phage grown in radioactive 32P, which is incorporated into phage DNA
Virus infect bacteria
Blender separates phage coat from bacteria
+
Centrifuge forms bacterial pellet
32P in bacteria pellet

The Hershey-Chase experiment, which demonstrated that the genetic material of phage is DNA, not protein. The experiment uses two sets of T2 bacteriophages. In one set, the protein coat is labelled with radioactive sulphur (^{35}S), not found in DNA.. In the other set, the DNA is labelled with radioactive phosphorus (^{32}P), not found in protein. Only the ^{32}P is injected into the *E. coli,* indicating that DNA is the agent necessary for the production of new phages.

Why such reluctance to accept this conclusion? DNA was thought to be a rather simple

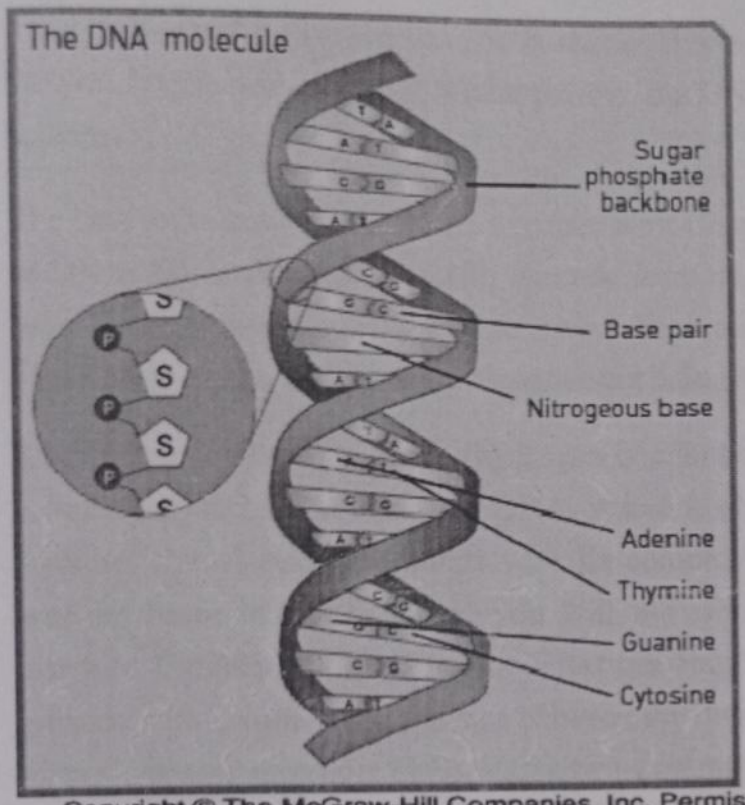
chemical. How could all the information about an organism's features be stored in such a simple molecule? How could such information be passed on from one generation to the next? Clearly, the genetic material must have both the ability to encode specific information and the capacity to duplicate that information precisely. What kind of structure could allow such complex functions in so simple a molecule?

Chargaff's Rules

Other important discoveries about DNA were made in the mid-1900s by Erwin Chargaff. He studied DNA from many different species. He was especially interested in the four different nitrogen bases of DNA: adenine (A), guanine (G), cytosine (C), and thymine (T) (see **Figure** below). Chargaff found that concentrations of the four bases differed from one species to another. However, within each species, the concentration of adenine was always about the same as the concentration of thymine. The same was true of the concentrations of guanine and cytosine. These observations came to be known as **Chargaff's rules**. The significance of the rules would not be revealed until the structure of DNA was discovered.

The Double Helix

After DNA was found to be the genetic material, scientists wanted to learn more about it. James Watson and Francis Crick are usually given credit for discovering that DNA has a **double helix** shape, like a spiral staircase (see **Figure** below). The discovery was based on the prior work of Rosalind Franklin and other scientists, who had used X rays to learn more about DNA's structure. Franklin and these other scientists have not always been given credit for their contributions. You can learn more about Franklin's work by watching the video at this link:http://www.youtube.com/watch?v=s3whouvZYG8 (7:47).



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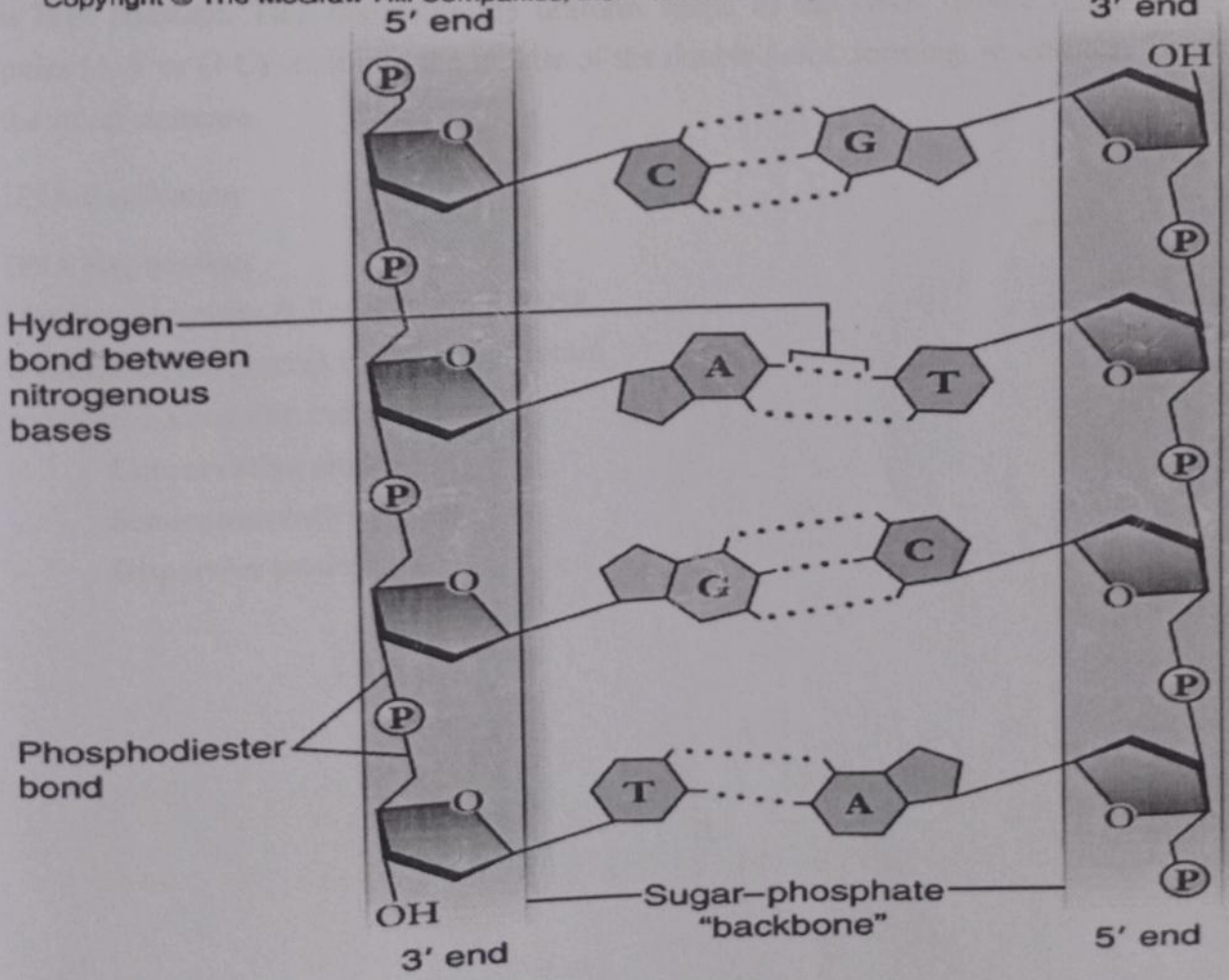

The DNA molecule has a double helix shape. This is the same basic shape as a spiral staircase. Do you see the resemblance? Which parts of the DNA molecule are like the steps of the spiral staircase?

The double helix shape of DNA, together with Chargaff's rules, led to a better understanding of DNA. DNA, as a nucleic acid, is made from **nucleotide** monomers, and the DNA double helix consists of two polynucleotide chains. Each nucleotide consists of a sugar (deoxyribose), a phosphate group, and a nitrogen-containing base (A, C, G, or T).

Scientists concluded that bonds (hydrogen bonds) between complementary bases hold together the two polynucleotide chains of DNA. Adenine always bonds with its complementary base, thymine. Cytosine always bonds with its complementary base, guanine. If you look at the nitrogen bases in **Figure** above, you will see why. Adenine and guanine have a two-ring structure. Cytosine and thymine have just one ring. If adenine were to bind with guanine and cytosine with thymine, the distance between the two DNA chains would be variable. However, when a one-ring molecule binds with a two-ring molecule, the distance between the two chains is kept constant. This maintains the uniform shape of the DNA double helix. These **base pairs** (A-T or G-C) stick into the middle of the double helix, forming, in essence, the steps of the spiral staircase.

DNA Replication

DNA Replication

Matthew Meselson & Franklin Stahl, 1958
investigated the process of DNA replication
considered 3 possible mechanisms:

- **Conservative model**
- **Semiconservative model**
- **Dispersive model**

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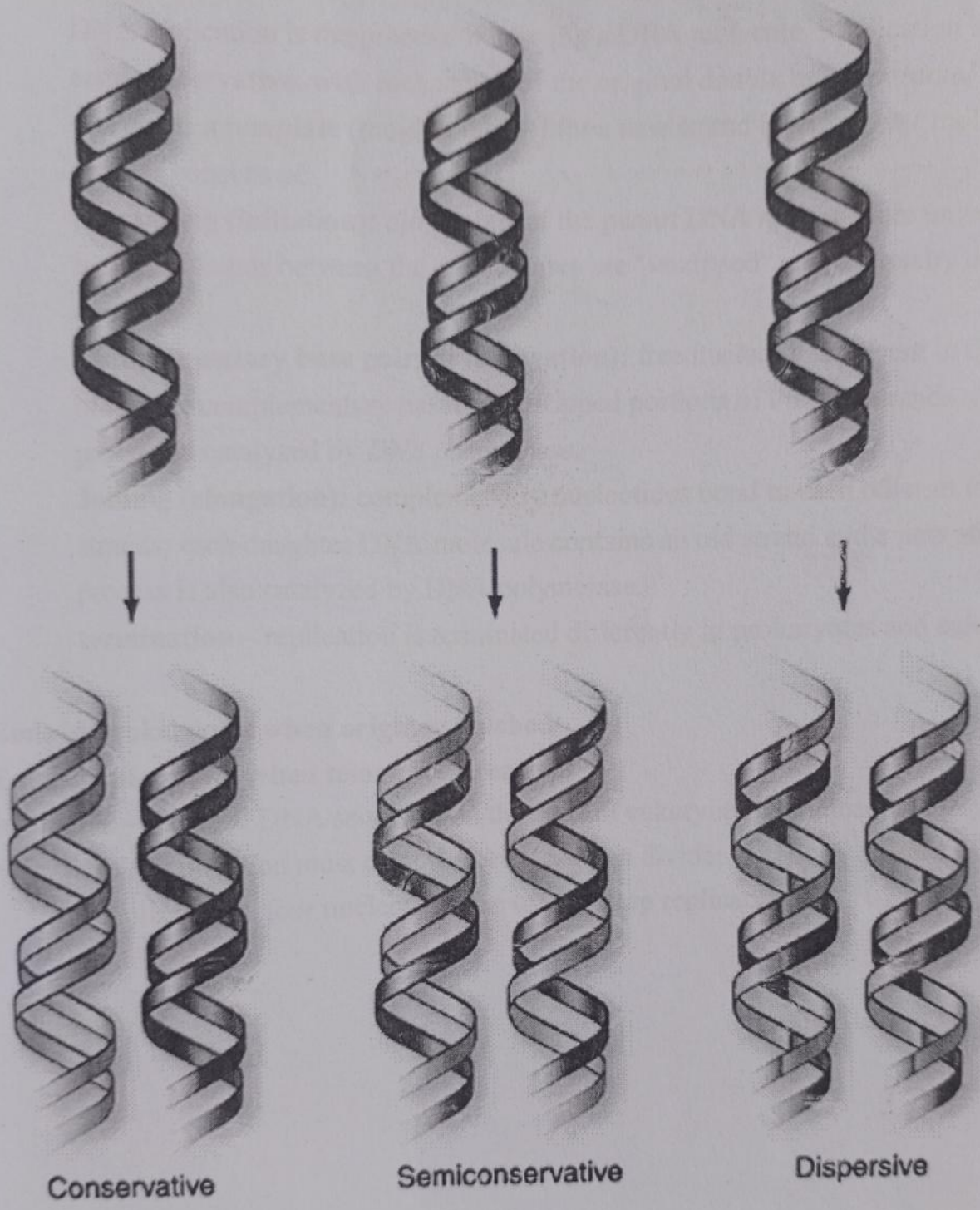

DNA

DNA Replication

Meselson and Stahl concluded that the mechanism of DNA replication is the **semiconservative model.**

Each strand of DNA acts as a template for the synthesis of a new strand.

DNA Replication

- DNA replication is the process of copying a DNA molecule. Replication is **semiconservative**, with each strand of the original double helix (*parental* molecule) serving as a **template** (mold or model) for a new strand in a *daughter* molecule. This process consists of:
- **Unwinding (initiation):** old strands of the parent DNA molecule are unwound as weak hydrogen bonds between the paired bases are "unzipped" and broken by the enzyme *helicase.*
- **Complementary base pairing (elongation):** free nucleotides present in the nucleus bind with complementary bases on unzipped portions of the two strands of DNA; this process is catalyzed by *DNA polymerase.*
- **Joining (elongation):** complementary nucleotides bond to each other to form new strands; each daughter DNA molecule contains an old strand and a new strand; this process is also catalyzed by DNA polymerase.
- **termination** – replication is terminated differently in prokaryotes and eukaryotes

Ends in prokaryotes when origin is reached

Ends in eukaryotes when telomere is reached

telomeres – repeated DNA sequence on the ends of eukaryotic chromosomes

- DNA replication must occur before a cell can divide; in cancer, drugs with molecules similar to the four nucleotides are used to stop replication.

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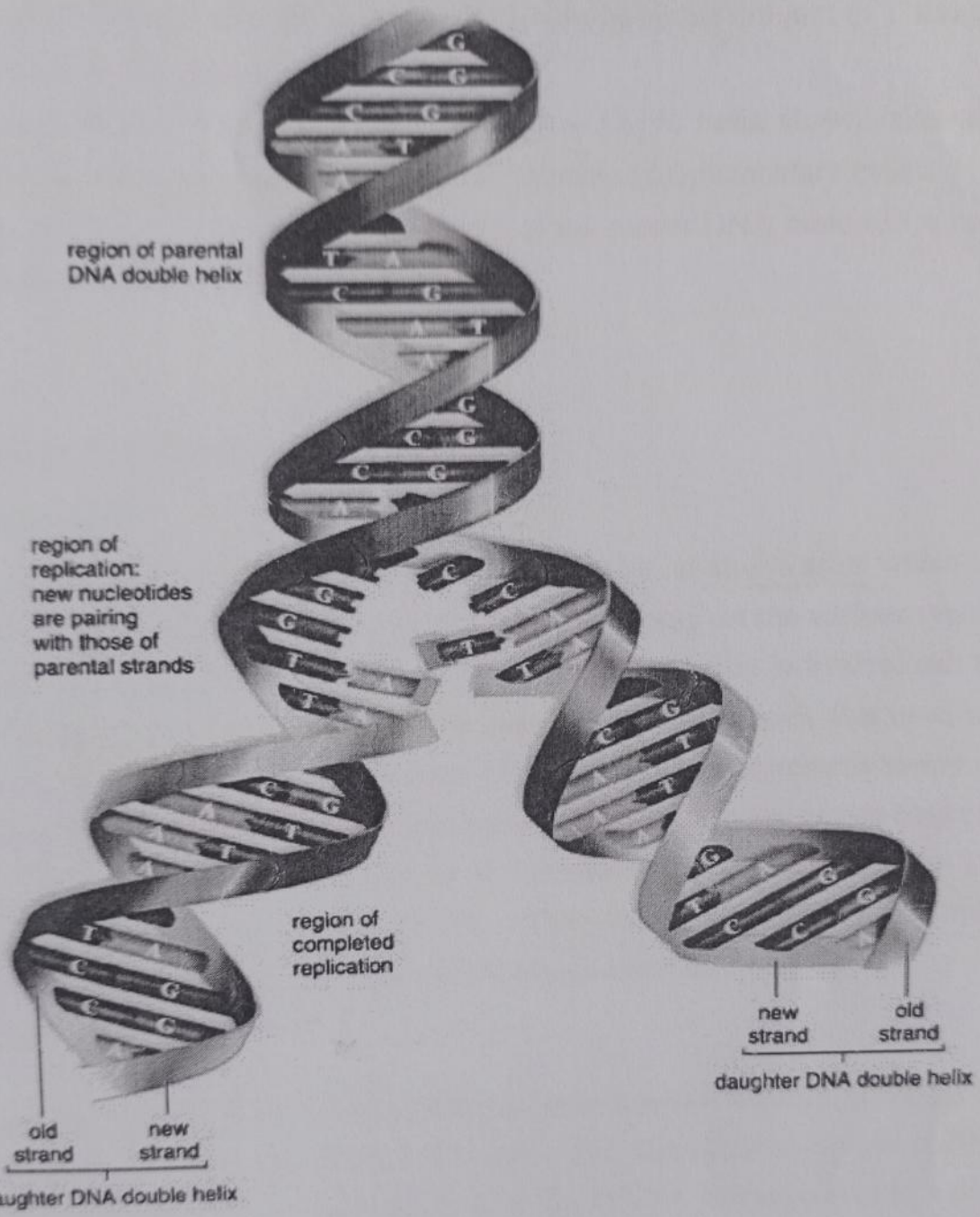

region of parental DNA double helix
region of replication: new nucleotides are pairing with those of parental strands
region of completed replication
old strand
new strand
daughter DNA double helix
new strand
old strand
daughter DNA double helix

- Replication Errors
  - A genetic mutation is a permanent change in the sequence of bases.
  - Base changes during replication are one way mutations occur.
  - A mismatched nucleotide may occur once per 100,000 base pairs, causing a pause in replication.
  - **Proofreading** is the removal of a mismatched nucleotide; **DNA repair enzymes** perform this proofreading function and reduce the error rate to one per billion base pairs.
  - Incorrect base pairs that survive the proofreading process contribute to gene mutations.

- Chargaff's rules state that the amount of A is similar to the amount of T and the amount of G is similar to the amount of C.
- Watson and Crick discovered that DNA has a double helix shape, consisting of two polynucleotide chains held together by bonds between complementary bases.
- DNA replication is semi-conservative: half of the parent DNA molecule is conserved in each of the two daughter DNA molecules.

6.0 PROTEIN SYNTHESIS

What is protein synthesis?

Proteins are important in building cells. They are chains of amino acids which are joined together to form different kinds of protein molecules depending on the various types of amino acids that join to form the proteins. The production of **protein** by an individual cell is called as **protein synthesis**. So the information on the sequence of amino acids that need to join in a specific order to form the right protein molecule for each of these proteins is stored in the gene which is in the DNA of the cell. **Protein synthesis** usually takes place in two major steps. The first step is Transcription which involves the creation of mRNA from the DNA. The second step involves the polymerization of amino acids to form polypeptides which is proteins as defined by the mRNA. This second step is called as **Translation**.

Transcription / DNA transcription

Transcription is the process by which the information in a strand of DNA is copied into a new molecule of messenger RNA (mRNA). DNA safely and stably stores genetic material in the nuclei of cells as a reference, or template. Meanwhile, mRNA is comparable to a copy from a reference book because it carries the same information as DNA but is not used for long-term storage and can freely exit the nucleus. Although the mRNA contains the same information, it is not an identical copy of the DNA segment, because its sequence is complementary to the DNA template.

Transcription is carried out by an enzyme called RNA polymerase and a number of accessory proteins called transcription factors. Transcription factors can bind to specific DNA sequences called enhancer and promoter sequences in order to recruit RNA polymerase to an appropriate transcription site. Together, the transcription factors and RNA polymerase form a complex

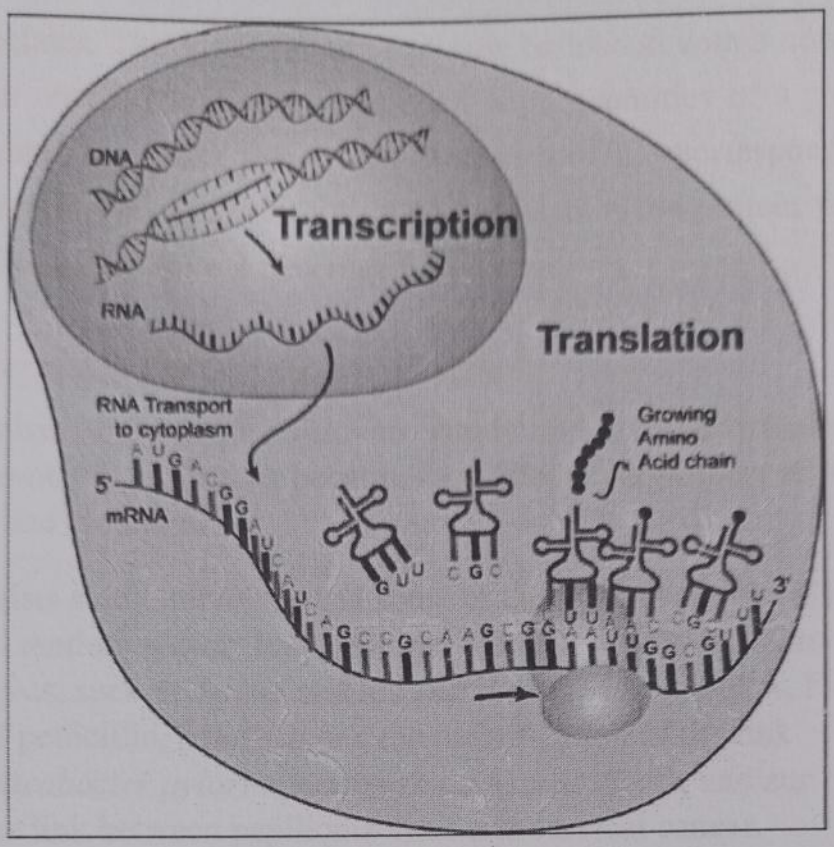
called the transcription initiation complex. This complex initiates transcription, and the RNA polymerase begins mRNA synthesis by matching complementary bases to the original DNA strand. The mRNA molecule is elongated and, once the strand is completely synthesized, transcription is terminated. The newly formed mRNA copies of the gene then serve as blueprints for protein synthesis during the process of translation.

Translation - Remember : 20 Amino Acids that must be expressed!

Translation is the final step on the way from DNA to protein. It is the synthesis of proteins directed by a mRNA template. The information contained in the nucleotide sequence of the mRNA is read as three letter words (triplets), called codons. Each word stands for one amino acid.

During translation amino acids are linked together to form a polypeptide chain which will later be folded into a protein. The translation is dependent on many components, of which two are extra important. First of all; the ribosome which is the cellular factory responsible for the protein synthesis. It consists of two different subunits, one small and one large and is built up from rRNA and proteins. Inside the ribosome the amino acids are linked together into a chain through multiple biochemical reactions.

The second component is the tRNA, a specialised RNA molecule that carries an amino acid at one end and has a triplet of nucleotides, an anticodon, at the other end. The anticodon of a tRNA molecule can base pair, i.e. form chemical bonds, with the mRNA's three letter codon.Thus the tRNA acts as the translator between mRNA and protein by bringing the specific amino acid coded for by the mRNA codon.



Translation process

the translation process is divided into three steps:

Initiation: When a small subunit of a ribosome charged with a tRNA+the amino acid methionine encounters an mRNA, it attaches and starts to scan for a start signal. When it finds the start sequence AUG, the codon (triplet) for the amino acid methionine, the large subunit joins the small one to form a complete ribosome and the protein synthesis is initiated.

Elongation: A new tRNA+amino acid enters the ribosome, at the next codon downstream of the AUG codon. If its anticodon matches the mRNA codon it basepairs and the ribosome can link the two aminoacids together.(If a tRNA with the wrong anticodon and therefore the wrong amino acid enters the ribosome, it can not basepair with the mRNA and is rejected.) The ribosome then moves one triplet forward and a new tRNA+amino acid can enter the ribosome and the procedure is repeated.

Termination: When the ribosome reaches one of three stop codons, for example UGA, there are no corresponding tRNAs to that sequence. Instead termination proteins bind to the ribosome and stimulate the release of the polypeptide chain (the protein), and the ribosome dissociates from the mRNA. When the ribosome is released from the mRNA, its large and

small subunit dissociates. The small subunit can now be loaded with a new tRNA+methionine and start translation once again. Some cells need large quantities of a particular protein. To meet this requirement they make many mRNA copies of the corresponding gene and have many ribosomes working on each mRNA. After translation the protein will usually undergo some further modifications before it becomes fully active.

7.0 INTRODUCTION TO MICROBIOLOGY

1. Micro-organisms and their activities are vitally important to virtually all processes on Earth. Micro-organisms matter because they affect every aspect of our lives – they are in us, on us and around us.

2. Microbiologists study microbes, and some of the most important discoveries that have underpinned modern society have resulted from the research of famous microbiologists, such as Jenner and his vaccine against smallpox, Fleming and the discovery of penicillin, Marshall and the identification of the link between *Helicobacter pylori* infection and stomach ulcers, and zur Hausen, who identified the link between papilloma virus and cervical cancer.

3. Microbiology research has been, and continues to be, central to meeting many of the current global aspirations and challenges, such as maintaining food, water and energy security for a healthy population on a habitable earth. Microbiology research will also help to answer big questions such as 'how diverse is life on Earth?', and 'does life exist elsewhere in the Universe'?

4. V

Microorganisms are the dominant life forms on earth, are found in almost every conceivable environment, and are essential to sustaining life on this planet. There are five basic groups of microorganisms:

- **Bacteria** are typically unicellular, microscopic, prokaryotic organisms that reproduce by binary fission.
- **Fungi** (yeasts and molds) are typically unicellular, microscopic, eukaryotic fungi that reproduce asexually by budding. Molds are typically filamentous, eukaryotic fungi that reproduce by producing asexual reproductive spores.
- **Viruses** are typically submicroscopic, acellular infectious particles that can only replicate inside a living host cell. The vast majority of viruses possess either DNA or RNA, but not both.
- **Protozoa** are typically unicellular, microscopic, eukaryotic organisms that lack a cell wall.
- **Algae** are typically eukaryotic microorganisms that carry out photosynthesis.

Benefits of Microbial Activity

Most people tend to think of microorganisms as harmful because of their roles in causing infectious diseases in humans and other animals, and agricultural loss as a result of infectious diseases of plants and the spoilage of food. The fact is, however, the vast majority of microorganisms are not harmful but rather beneficial. Without them there would be no life on earth. Therefore, we will start this course by looking at a few of the many benefits from microbial activity on this planet.

1. **Food production:** Many food products employ microorganisms in their production. These include the microbial fermentation processes used to produce yogurt, buttermilk, cheeses, alcoholic beverages, leavened breads, sauerkraut, pickles, and kimchi.
2. **Energy production and cleaning up the environment**: Methane, or natural gas, is a product of *methanogenic microorganisms*. Many aquatic microbes capture light energy and store it in molecules used as food then used by other organisms. Animal wastes, domestic refuse, biomass, and grain can be converted to biofuels such as ethanol and methane by microorganisms. In addition, through a process called bioremediation , some pollutants such pesticides, solvents, and oil spills can be cleaned up with the aid of microbes.
3. **Sustaining agriculture**: Through their roles in recycling nitrogen, carbon, and sulfur, microorganism are able to convert these essential elements into forms that can be used by plants in their growth. They are also essential in enabling ruminant animals such as cows and sheep to digest cellulose from the grasses they eat.
4. **Production of useful natural gene products or products from bioengineering.** Examples include specific enzymes, antibiotics, vaccines, and medications such as human insulin, interferons, and growth hormones.
5. **The human microbiota and microbiome**: Where we be without microorganisms? While the typical human body contains an estimated 37 trillion human cells, it also contains over 100 trillion bacteria and other microbes. The human body has 3 times as many bacterial cells as it does human cells! It is estimated the the mass of the human microbiota is 2.5 pounds.

The complex mutually beneficial symbiotic relationship between humans and their natural microbes is critical to good health. It is now recognized that the millions of genes associated with the microbiota of the human body -especially in the intestinal tract - aid in the digestion of many foods, the regulation of multiple host metabolic pathways, and the regulation the body's immune defenses. These collective microbes and their genes are referred to as the human microbiome. There are currently an estimated 5,000,000 - 10,000,000 genes from over 1000 species that constitute the human microbiome compared to the approximately 20,000 - 23,000 genes that make up the human genome. There are approximately 300 non-human genes in the human body for every human gene.

a. Regulation of Host Metabolism

The mutually beneficial interaction between the human host and its resident microbiota

is essential to human health. Microbial genes produce metabolites essential to the host while human genes contribute to development of the microbiota. The microbiome aids in the following:

1. The digestion of many foods, especially plant polysaccharides that would normally be indigestible by humans.
2. The regulation of many host metabolic pathways. The metabolism of many substrates in the human body is carried out by a combination of genes from both the microbiome and the human genome. Within the intestinal tract there is constant chemical communication not only between microbial species but also between microbial cells and human cells. Multiple factors, including diet, antibiotic use, disease, life style, and a person's environment can alter the composition of the microbiota within the gastrointestinal tract and, as a result, influence host biochemistry and the body's susceptibility to disease.
3. Metabolic disorders such as diabetes, nonalcoholic fatty liver disease, hypertension, obesity, gastric ulcers, colon cancer, and possibly some mood and behavior changes through hormone signaling have been linked to alterations in the microbiota.

b. Regulation of Immunity

There is ever growing evidence that commensal bacteria of the gastrointestinal tract, as well as parasitic gastrointestinal helminths, may have coevolved with the human body over the past 200,000 year in such a way that genes from the human microbiota may play a significant role in regulating the human immune responses by providing a series of checks and balances that prevent the immune system from being too aggressive and causing an autoimmune attack upon the body's own cells, while still remaining aggressive enough to recognize and remove harmful pathogens. The microbiota affects the development of the immune system while the immune system influences the composition of the microbiota.

As exposure to and colonization with these once common human organisms has drastically changed over time as a result of less exposure to mud, animal and human feces,and helminth ova, coupled with ever increasing antibiotic use that destroys normal flora, improved sanitation, changes in the human diet, increased rate of cesarean sections, decreased rate of breast feeding, and improved methods of processing and preserving of food, the rates of allergies, allergic asthma, and autoimmune diseases (inflammatory bowel disease, Crone's disease, irritable bowel syndrome, type-1 and type-2 diabetes, and multiple sclerosis for example) have dramatically increased in developed countries while remaining relatively low in undeveloped and more agrarian parts of the world.

Summary

1. Microorganisms are typically too small to be seen with the naked eye.
2. Bacteria, fungi, viruses, protozoa, and algae are the major groups of microorganisms.
3. The vast majority of microorganisms are not harmful but rather beneficial.
4. Microbiota refers to all of the microorganisms that live in a particular environment.
5. A microbiome is the entire collection of genes found in all of the microbes associated with a particular host.
6. The microbiome of the human body - especially in the intestinal tract - aid in the digestion of many foods, the regulation of multiple host metabolic pathways, and the regulation the body's immune defenses.

8.0 ECOLOGY

Introduction

Ecology is a new science and considered as an important branch of biological science, having only become prominent during the second half of the 20th century. Ecological thought is derivative of established currents in philosophy, particularly from ethics and politics.

Its history stems all the way back to the 4th century. One of the first ecologists whose writings survived may have been Aristotle or perhaps his student, Theophrastus, both of whom had interest in many species of animals and plants. Theophrastus described interrelationships between animals and their environment as early as the 4th century BC. Ecology developed substantially in the 18th and 19th century. It began with Carl Linnaeus and his work with the economy of nature. Soon after came Alexander von Humboldt and his work with botanical geography. Alexander von Humboldt and Karl Möbius then contributed with the notion of biocoenosis. Eugenius Warming's work with ecological plant geography led to the founding of ecology as a discipline. Charles Darwin's work also contributed to the science of ecology, and Darwin is often attributed with progressing the discipline more than anyone else in its young history. Ecological thought expanded even more in the early 20th century.

Ecology influenced the social sciences and humanities. Human ecology began in the early 20th century and it recognized humans as an ecological factor. Later James Lovelock advanced views on earth as a macro-organism with the Gaia hypothesis. Conservation stemmed from the science of ecology.

Timeline of ecologists

A list of founders, innovators and their significant contributions to ecology, from Romanticis

Notable figure	Lifespan	Major contribution & citation
Antonie van Leeuwenhoek	1632–1723	First to develop concept of Food Chains
Carl Linnaeus	1707–1778	Influential naturalist, inventor of science on the economy of nature

Alexander Humboldt	1769–1859	First to describe ecological Gradient of latitudinal biodiversity increase toward the tropics in 1807
Charles Darwin	1809–1882	Founder of the hypothesis of evolution by means of natural selection, founder of ecological studies of soils
Elizabeth Catherine Thomas Carne	1817-1873	Geologist, mineralogist and philosopherwho observed ruralvs urban living, spatially and culturally, finding in country living the best attack on suffocating class divides, healthier living, and best access to natural education.
Herbert Spencer	1820–1903	Early founder of social ecology, coined the phrase 'survival of the fittest
Karl Möbius	1825–1908	First to develop concept of ecological community, biocenosis, or living community
Ernst Haeckel	1834–1919	Invented the term ecology, popularized research links between ecology and evolution
Victor Hensen	1835–1924	Invented term plankton, Developed quantitative and statistical measures of productivity in the seas
Eugenius Warming	1841–1924	Early founder of Ecological Plant Geography
Ellen Swallow Richards	1842–1911	Pioneer and educator who linked urban ecology to human health
Stephen Forbes	1844–1930	Early founder of entomology and ecological concepts in 1887

		models around the same time as Alfred J. Lotka.
Vladimir Vernadsky	1869–1939	Founded the biosphere Concept
Henry C. Cowles	1869–1939	Pioneering studies and Conceptual development in studies of ecological succession
Jan Christiaan Smuts	1870–1950	Coined the term holism in a 1926 book *Holism and Evolution.*
Arthur G. Tansley	1871–1955	First to coin the term ecosystem in 1936 and notable researcher
Charles Christopher Adams	1873–1955	Animal ecologist, biogeographer, author of first American book on animal ecology in 913, founded ecological energetics
Friedrich Ratzel	1844–1904	German geographer who first Coined the term biogeography in 1891.
Frederic Clements	1874–1945	Authored the first influential American ecology book in 1905
Victor Ernest Shelford	1877–1968	Founded physiological ecology, Pioneered food-web and Biome concepts, founded The Nature Conservancy
Alfred J. Lotka	1880–1949	First to pioneer mathematical Populations models explaining trophic (predator-prey) interactions using logistic equation

Henry Gleason	1882–1975	Early ecology pioneer, Quantitative theorist, author, and founder of the individualistic concept of ecology
Charles S. Elton	1900–1991	'Father' of animal ecology, Pioneered food-web & niche concepts and authored influential *Animal Ecology*
G. Evelyn Hutchinson	1903–1991	Limnologist and conceptually advanced the niche concept
Eugene P. Odum	1913–2002	Co-founder of ecosystem ecology and ecological thermodynamic concepts
Howard T. Odum	1924–2002	Co-founder of ecosystem ecology and ecological thermodynamic concepts
Robert MacArthur	1930–1972	Co-founder on Theory of Island Biogeography and innovator of ecological statistical methods[97]

Ecological Influence on the Social Sciences and Humanities

Human ecology

Human ecology began in the 1920s, through the study of changes in vegetation succession in the city of Chicago. It became a distinct field of study in the 1970s. This marked the first recognition that humans, who had colonized all of the Earth's continents, were a major ecological factor. Humans greatly modify the environment through the development of the habitat (in particular urban planning), by intensive exploitation activities such as logging and fishing, and as side effects of agriculture, mining, and industry. Besides ecology and biology, this discipline involved many other natural and social sciences, such as anthropology and ethnology, economics, demography, architecture and urban planning, medicine and psychology, and many more. The development of human ecology led to the increasing role of ecological science in the design and management of cities.

In recent years human ecology has been a topic that has interested organizational researchers. Hannan and Freeman (*Population Ecology of Organizations (1977)*, American Journal of Sociology) argue that organizations do not only adapt to an environment. Instead it is also the

environment that selects or rejects populations of organizations. In any given environment (in equilibrium) there will only be one form of organization (isomorphism). Organizational ecology has been a prominent theory in accounting for diversities of organizations and their changing composition over time.

History and relationship between ecology and conservation and environmental movements

Environmentalists and other conservationists have used ecology and other sciences (e.g., climatology) to support their advocacy positions. Environmentalist views are often controversial for political or economic reasons. As a result, some scientific work in ecology directly influences policy and political debate; these in turn often direct ecological research.

The history of ecology, however, should not be conflated with that of environmental thought. Ecology as a modern science traces only from Darwin's publication of Origin of Species and Haeckel's subsequent naming of the science needed to study Darwin's theory. Awareness of humankind's effect on its environment has been traced to Gilbert White in 18th-century. Ecology before Darwin, however, is analogous to medicine prior to Pasteur's discovery of the infectious nature of disease.

Roosevelt & American conservation

Theodore Roosevelt was interested in nature from a young age. He carried his passion for nature into his political policies. Roosevelt felt it was necessary to preserve the resources of the nation and its environment. In 1902 he created the federal reclamation service, which reclaimed land for agriculture. He also created the Bureau of Forestry. This organization, headed by Gifford Pinchot, was formed to manage and maintain the nations timberlands. Roosevelt signed the Act for the Preservation of American Antiquities in 1906. This act allowed for him to "declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of historic and scientific interest that are situated upon lands owned or controlled by the Government of the United States to be national monuments." Under this act he created up to 18 national monuments. During his presidency, Roosevelt established 51 Federal Bird Reservations, 4 National Game Preserves, 150 National Forests, and 5 National Parks. Overall he protected over 200 million acres of land.

Ecology and global policy

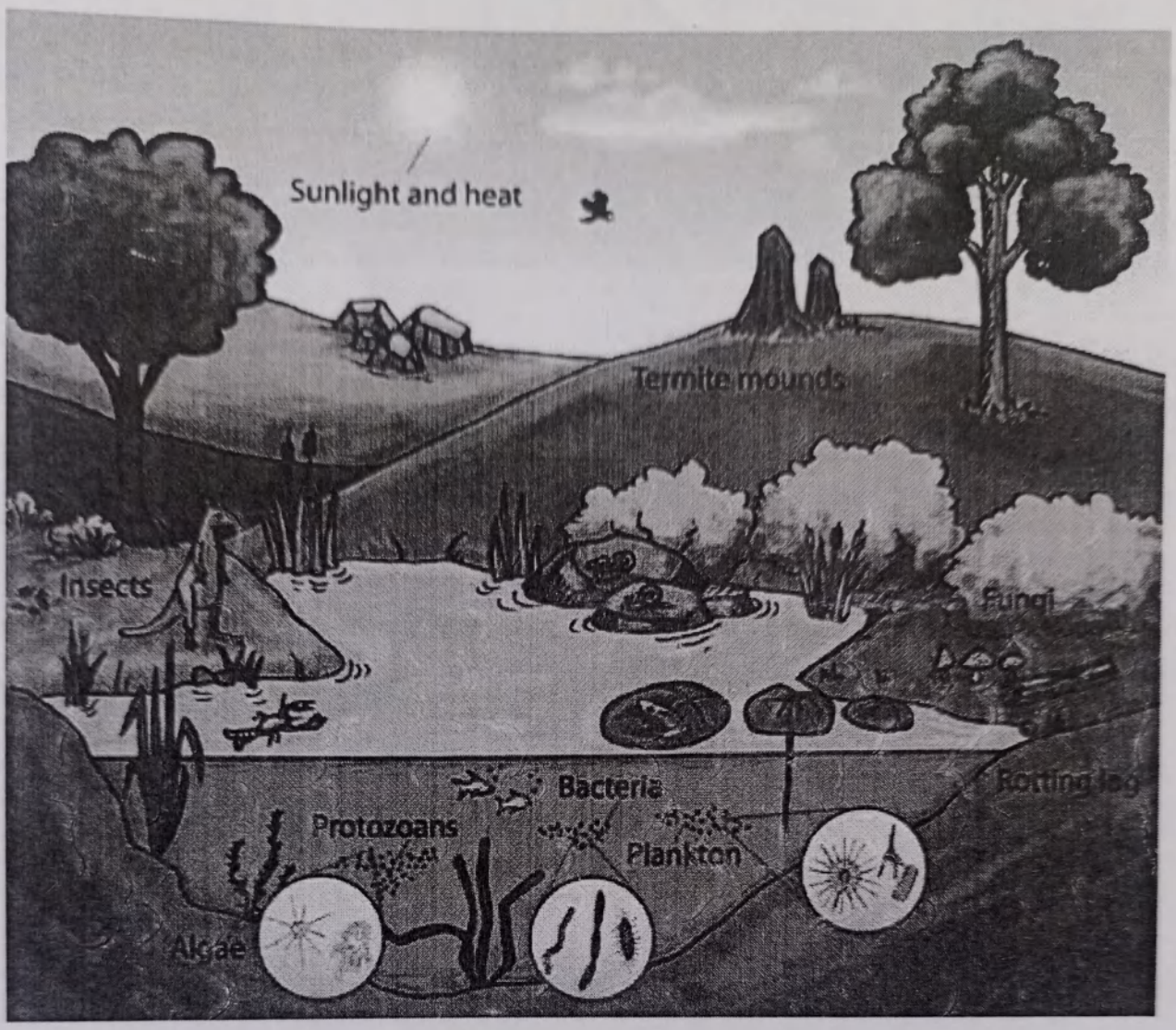
Ecology became a central part of the World's politics as early as 1971, UNESCO launched a research program called *Man and Biosphere*, with the objective of increasing knowledge about the mutual relationship between humans and nature. A few years later it defined the concept of Biosphere Reserve.

In 1972, the United Nations held the first international Conference on the Human Environment in Stockholm, prepared by Rene Dubos and other experts. This conference was

the origin of the phrase "Think Globally, Act Locally". The next major events in ecology were the development of the concept of biosphere and the appearance of terms "biological diversity"—or now more commonly biodiversity—in the 1980s. These terms were developed during the Earth Summit in Rio de Janeiro in 1992, where the concept of the biosphere was recognized by the major international organizations, and risks associated with reductions in biodiversity were publicly acknowledged.

Then, in 1997, the dangers the biosphere was facing were recognized all over the world at the conference leading to the Kyoto Protocol. In particular, this conference highlighted the increasing dangers of the greenhouse effect – related to the increasing concentration of greenhouse gases in the atmosphere, leading to global changes in climate. In Kyoto, most of the world's nations recognized the importance of looking at ecology from a global point of view, on a worldwide scale, and to take into account the impact of humans on the Earth's environment.

Ecology was formed from two Greek words [Gk: oikos; home and logos; the study of] to denote the relationship between organisms and their environment. Ecology therefore means the study of an organism in its natural home. Odum (1963) defined ecology as the study of the structure and function of nature or the study of inter-relationships between organisms and their environment. It has to do with the relationship between living organism (biotic factors) and their physical environments (abiotic factors).



The Environments depict the network of relations between living organisms at different scales. Since the environment has different forms of biodiversity, scientists research everything from little microbes in nutrient recycling to the impacts of tropical rain forests on the Earth's environment. Researchers who study ecology are called ecologists.

Ecology has to do with:

- Distribution and abundance of organisms
- The movement of materials and energy through living communities
- The successional development of ecosystems
- The abundance and distribution of biodiversity in the context of the environment.

Branches of ecology

There are two branches of Ecology:

1. **Autecology**
2. **Synecology**

Autecology- It is the study of ecology at the level of species. It is the study of the interactions of an individual life form or a single species with the living and nonliving components of its environment.

Synecology- It is the study of ecology at the level of communities. It is a study of the development, distribution, and structure of ecological communities.

Types of Ecology

There are various kinds of ecology and they are given below:

- **Global Ecology** - Global ecology is the study of the interactions among the Earth's environments, land, air, and seas.
- **Landscape Ecology** - It deals with the study of the exchange of vitality, materials, living beings, and various other parts of the ecosystem. It also depicts the role of human impacts on landscape structures and functions.
- **Ecosystem Ecology**- Ecosystem ecology is the integrated study of living and non-living components of biological systems. It also deals with their interactions inside an ecosystem.
- **Community Ecology** - It is the study of the function and organization of communities between organisms.
- **Population Ecology** - It deals with components that change and affect the hereditary composition and the size of the population of life forms. Biologists are fascinated by the variations in a population, the development of a population, and any other interactions with the population
- **Organismal Ecology** - Organismal ecology is the study of an individual organism's

conduct, morphology, physiology, etc. to natural changes.

- **Molecular Ecology** - Molecular ecology is the study of the environment on the generation of proteins and how these proteins influence life forms and their environment. This happens at the molecular level. DNA shapes the proteins that are connected with the environment. These interactions give rise to a few complex living beings.

Concepts of Ecology

Ecological Levels of Organization: Ecological hierarchy follows the below order with an increase in size and complexity

Organism → Species (population) → Biotic community → Ecosystem → Biome → Biosphere

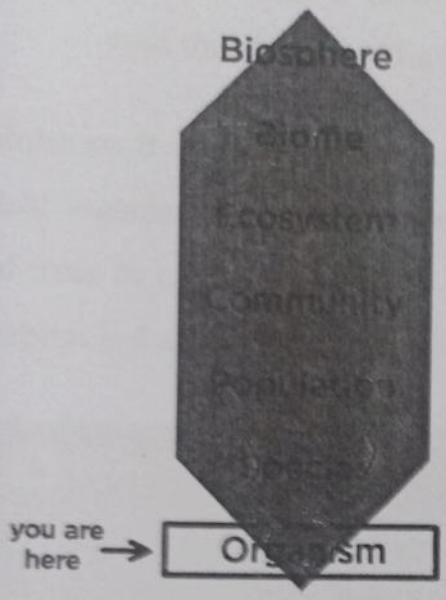
- ✓ **Organism:** Individual living entities. It includes all the living organisms, unicellular or multicellular having a fixed lifespan.

A living thing has to have eight features:

1. It is made of at least one cell.
2. It can reproduce, either asexually or sexually.
3. It contains DNA that can be inherited from its parent or parents, and can pass on genetic information to offspring.
4. It grows and develops.
5. It uses energy.
6. It maintains its internal environment.
7. It is involved in evolution.
8. It can respond to its environment.

If a thing has all of these features, it is a living thing.

Levels of Biological Organization: Organism



What is an organism?

An organism is any living thing, from a bacterium to a giraffe.

An organism must:
- be made of at least one cell
- contain DNA
- grow and develop
- have the ability to reproduce
- obtain and use energy
- maintain homeostasis
- respond to its surroundings

How is it different from a species?

Species is a category that includes all organisms around the world that look similar, can interbreed, and produce fertile offspring. All humans are organisms that belong to the same species, Homo sapiens.

- ✓ **Population or Species:** Group of organisms of the same species occupying a particular area and interbreeding. A species is a group of organisms that have a common gene pool and can interbreed to produce fertile offspring

- **Endemic species** are found only in a particular area, e.g. kangaroos found in Australia
- **Key-stone species** is mostly a predator species, which is not present in large number but has a major influence on the characteristics of a community, e.g. lion in the forest.
- **Critical Link species,** which help other species in the vital activities, e.g. pollinators for plants, parasitic and symbiotic relationships.

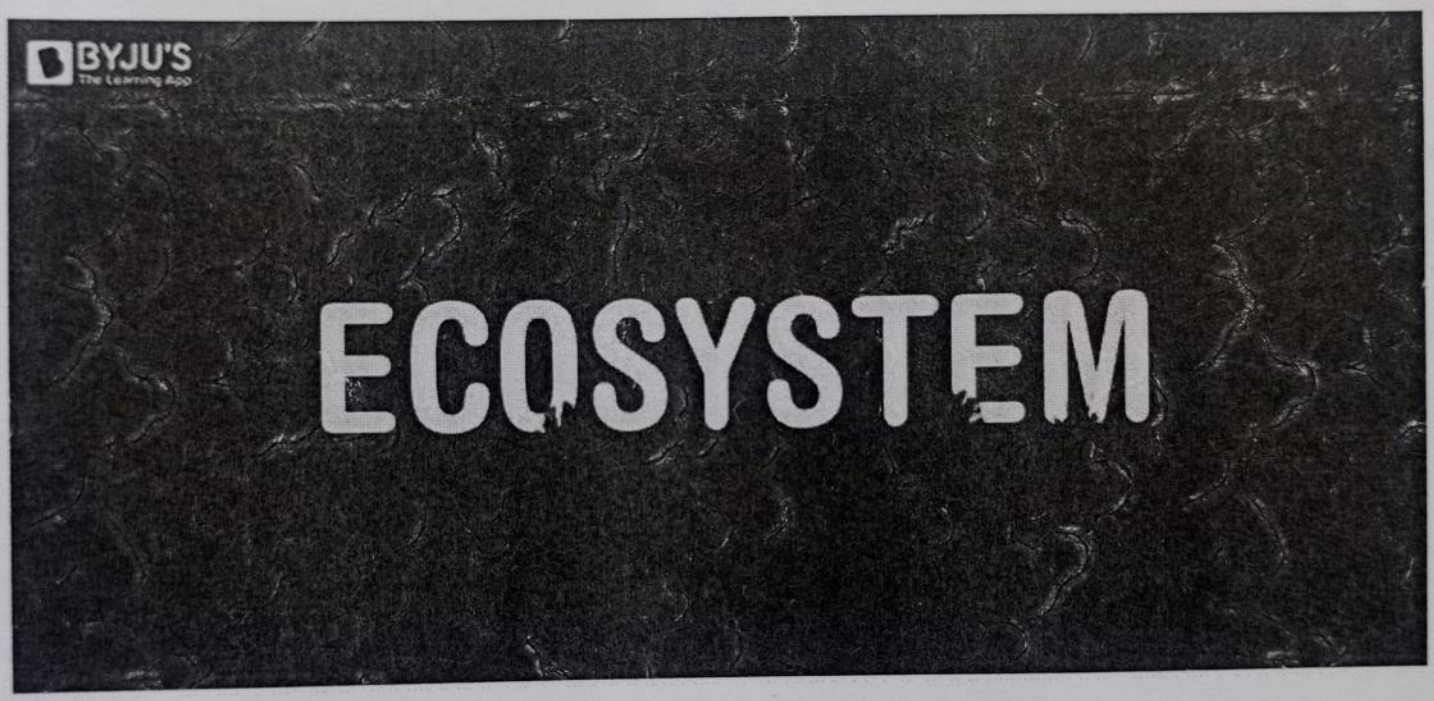
- ✓ **Community**: All the populations of different species that inhabit a particular area and interact with each other.

- ✓ **Ecosystem**: A biological community of organisms and their physical environment. Biotic components and abiotic components constitute an ecosystem.

- ✓ **Biome:** consists of communities present in a large geographical area.

- ✓ **Biosphere:** The global sum of all ecosystems. It can also be referred to as the zone of life on Earth. It involves all the living organisms, their relationships and interaction with the elements of atmosphere, hydrosphere and lithosphere.

Habitat: It is a natural environment of an organism where it grows, lives and reproduces. A host organism inhabited by parasites is as much a habitat as a terrestrial place such as a grove of trees or an aquatic locality such as a small pond. Life exists not only in the most favorable habitat but also in the most extreme and harsh environment.



THE CONCEPT OF ECOSYSTEM

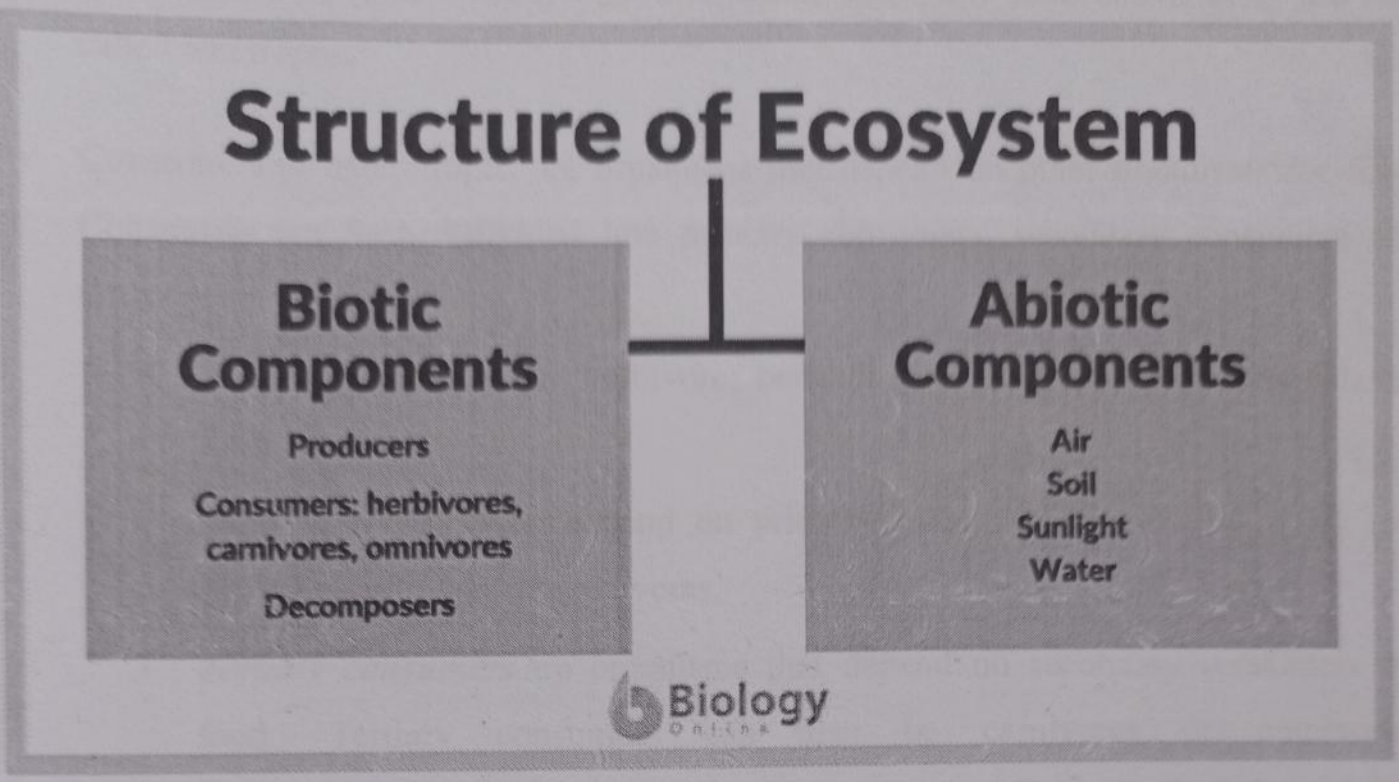
DEFINITION OF ECOSYSTEM: An **ecosystem** is a system consisting of biotic and abiotic components that function together as a unit.

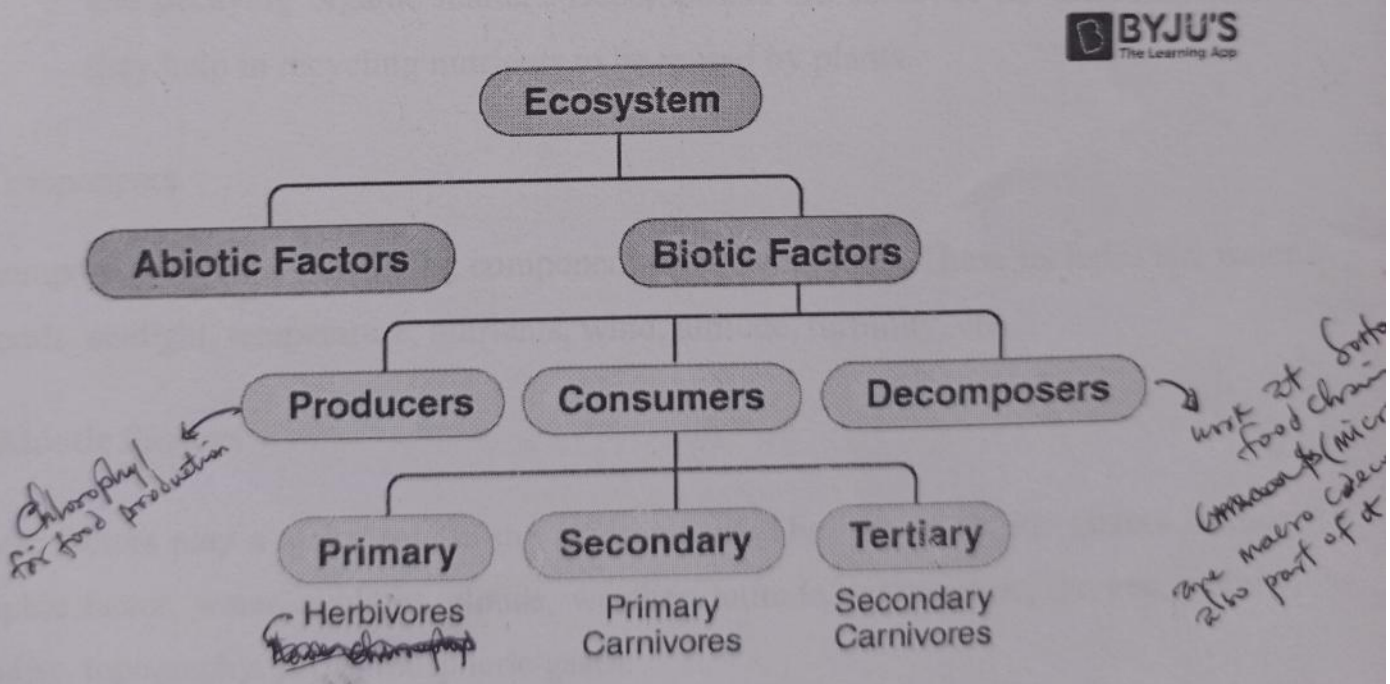
Ecosystem Structure

The ecosystem structure consists of two major components:

(1) **biotic components**

(2) **abiotic components**





Biotic components refer to all living components in an ecosystem. Ecosystem contains the following

- **Primary producers** (plants) capable of taking energy from the sun through the process

called photosynthesis. This energy then flows through a food chain. They are also called autotrophs.

- **Consumers** or heterotrophs are organisms that depend on other organisms for food. Consumers are further divided into primary consumers, secondary consumers and tertiary consumers.
    - ***Primary consumers*** are herbivores because they depend on producers (plants) for food.
    - ***Secondary consumers*** depend on primary consumers for energy. They can either be carnivores or omnivores.
    - ***Tertiary consumers*** are organisms that depend on secondary consumers for food. Tertiary consumers can also be carnivores or omnivores. **Decomposers:** decomposers work at the bottom of the food chain and this include saprophytes such as fungi and bacteria. They directly thrive on the dead and decaying organic matter. Decomposers are essential for the ecosystem as they help in recycling nutrients to be reused by plants.

Abiotic Components

Abiotic components are the non-living component of an ecosystem. These includes air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc.

Lists of Abiotic Factors

The abiotic factors play a major role in the environment. The lists of abiotic factors include: soil- edaphic factor, water, sunlight, clouds, weather, latitude, temperature, oxygen, salinity, air, humidity, topography, pH, Atmospheric gases.

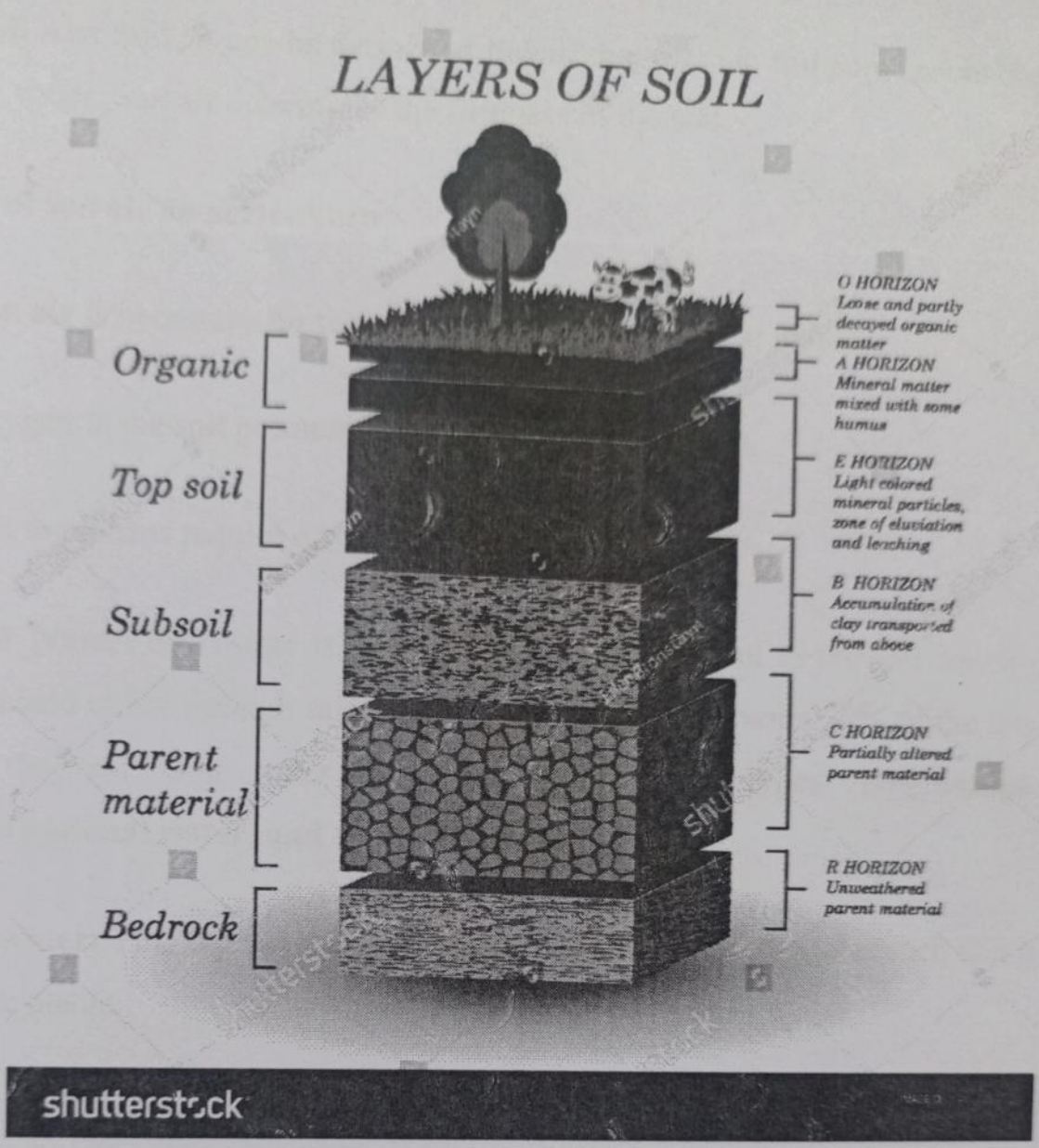
- **Soil – edaphic factor:** edaphic factors are factors that relates to structure and composition of the soil. Soil is a very complex medium and a good fertile soil contains mineral matter of about 40%, organic matter 10%, water 15% and air about 25%. Under edaphic factors we will be looking at some important factors

Edaphic factor

- ✓ **Soil texture:** soil texture refers to the relative proportion (sizes) of the various particles of the soil. The particles that make up a soil sample include sand, gravel, silt, and clay. Sand, silt and clay are usually referred to as the primary particles. Sandy soils drain quickly but may not retain nutrients, while clayey soils hold water but can become compacted. The right balance of soil texture is crucial for water retention and nutrient availability.

  Importance of Soil Texture: soil texture plays crucial role for nutrient supplies, aeration, root development, and moisture content.

- ✓ **Soil profile:** soil profile is defined as the vertical section of the soil, showing series of horizontal layers of different types of soil. These horizontal layers are called **horizons**. If a pit is dug in the soil, at least 1 m deep, various layers, different in colour and composition can be seen. These layers are called horizons. This succession of horizons is called the profile of the soil



Importance of Soil Profile

The suitability of the soil for agriculture is determined by looking at the soil profile. The importance of soil profile includes:

Level of soil fertility: soil profile determines the level of soil fertility. A thick top soil represents high level of soil fertility.

To know the kind of crop to grow: shallow rooted crops like cowpea and groundnut are grown in the top soil, while deep rooted crops are grown where the sub soil is thick.

Penetration of roots: a loosely packed sub-soil allows for easy penetration of roots of crops.

- ✓ **Soil Air:** Soil air can be defined as the air that fills the soil pore spaces not occupied by water. Soil air determines the firmness of the soil.

Importance of soil air on agriculture

1. **Soil air** is necessary for the growth and development of plants.
2. Oxygen in the soil promotes easy germination of seeds.
3. Soil organisms require oxygen for respiration.

- ✓ **Soil Water:** Soil water is defined as the water present in the soil which is usually obtained either through rain or irrigation. Water represents 25% of the total volume of the soil. Soil water is classified into three types- **Hygroscopic water, gravitational water, and capillary water.**

Hygroscopic water: This type of water is tightly held by the soil particles such that it is never available to the plants.

Gravitational water: water moving down freely due to gravity.

Capillary water: this is the water which rises above the water table in the soil and it is held in the fine and medium pores of soil particles by surface tension.

- ✓ **Soil pH:** The word pH is defined as the measure of the degree of acidity or alkalinity of the soil. A higher concentration of hydrogen ions indicates soil acidity while a lower concentration of hydrogen ions shows soil alkalinity.

- ✓ **Soil organisms:** this refers to the animals that inhabits the soil. They range from microscopic organisms to bigger organisms.

- **Light:** light is the primary source of energy to almost all ecosystems. The light energy is by plants to manufacture their own food through the process called photosynthesis.

Sunlight is necessary for photosynthesis, the process by which plants convert carbon dioxide (CO2) and water to oxygen (O2) and sugar – food for the plants that later becomes food for animals. Without the sun, plants cannot live, and without plants, animals cannot live.

- **Temperature:** Temperature is an abiotic factor that is strongly influenced by sunlight. Temperature plays an important role for animals that cannot regulate their own body temperature, such as reptiles. The temperature of the air and the water affect the animals, plants, and humans in nature. A rise in temperature is capable of changing the way a living thing develops. This is because it changes the metabolic rate of organisms. The blooming of flowers either in the day or night is due to the temperature difference between day and night.

Water: water is essential for life and all the biotic component of the ecosystem are directly dependent on water for survival. About 70% of our body is made up of water.

1. Water is the most abundant natural resource on the earth's surface. It is also the most important need of all living things.
2. The presence of water is necessary for several life processes, such as the germination of seeds, the digestion and absorption of food, the removal of waste products, the absorption of nutrients, and the circulation of substances in the body require water as a medium.
3. The amount of water in the habitat affects the types of flora and fauna found in that habitat.

For example, there is less vegetation in desert areas where water is scarce.

5. On the other hand, in areas with high rainfall, a wide variety of plants grow thickly, forming tropical rainforests. This provides a very rich environment for animals, with a wide variety of animals thriving.
6. Water can dissolve gases such as oxygen and carbon dioxide. Water also contains dissolved salts and minerals. Both plants and animals can survive in water.

- Land animals are prone to desiccation and these animals show various types of adaptations to this. Some of the adaptations are

Based on their water requirement plants are classified based on the following

- ✓ Hydrophytes: Plants that are adapted to live in aquatic environments are called hydrophytes. They might be fully submerged, partially submerged or floating in water. These plants have special adaptations that help them to survive in water. Example water lily

- ✓ Mesophytes: A majority of plants living on this planet are mesophytes. These are the plants that can survive in moderate environments that are neither particularly dry nor particularly wet. They thrive in soil that is not swamped in water and has moderate salt content and humidity. Example: corn, rose, clover, squash,

- ✓ Xerophytes: Plants that are adapted to survive in physiologically dry conditions are called xerophytes. They have special adaptations to prevent loss of water, and also store some water. Plants that store water are called succulents, e.g, cacti, agave. They have thick and fleshy stems that are able to store water. This water can be used whenever required.

MEANING AND TYPES OF HABITAT IN ECOLOGY

A **habitat** is a place where an organism lives or makes its home.
Habitats must meet all the requirements for an organism to survive, such as having enough resources to sustain populations of organisms that can mate and reproduce.

Traditionally, when we think of habitats, we think of a place we inhabit or live in. And while this is true, habitats often include many types of organisms that can survive in the same area because of their adaptations.

We need to consider abiotic and biotic factors when we talk about habitats. Abiotic factors are non-living things such as water, the sky, and other physical surroundings of the environment. In contrast, biotic factors are comprises living things, such as the different organisms in the habitat.

We also must consider that almost any space on earth can be a habitat. Habitats can range from microscopic, such as intestinal flora and fauna, to biomes, such as land or terrestrial.

Microhabitats are tiny areas that differ from the surrounding environments. A microhabitat's

distinctive features allow it to house unique habitats. An example of a microhabitat could be an overturned log, an organism's gut, etc.

Generally, we think of terrestrial, land, and water or aquatic habitats when referring to habitats. The following sections will review some of the different terrestrial and aquatic habitats.

- Terrestrial habitat
- Aquatic habitat

Terrestrial habitat

Terrestrial habitat are exclusively land-based ecosystems. There are different types of terrestrial habitat distributed around various geological zones. They are as follows:

1. Forest habitat

   - There are different types of forest habitats and these includes: tropical forest, temperate (examples are Temperate Deciduous Forest, Temperate Coniferous Forest habitat) forest , boreal forest , savanna forest habitats.

2. Grassland habitat
3. Tundra habitat
4. Desert habitat
5. Taiga habitat

Of the three major types of habitats, terrestrial is the most variable. In altitude it ranges from below sea-level (Death-valley) to mountain peaks more than 28,000 feet in height.

A considerable variation of temperature is encountered in terrestrial habitats.

(i) Tundra:

The arctic region of North America, Europe and Asia is known as Tundra region. Tundra region consist of two types; **arctic** and **alpine**. The Arctic tundra is located in the Arctic Circle, north of the boreal forests. Alpine tundra occur on mountain tops. Both types experience cold temperatures throughout the year. This region is treeless, and is characterized by long-cold winter with little or no sunlight. The summer is cool, short, and is with long daylight hours.

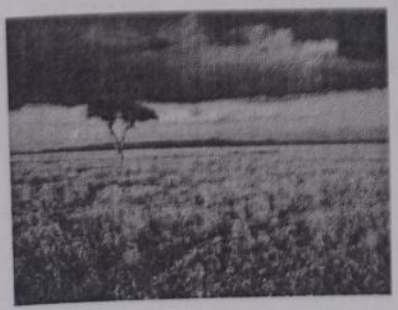
(ii) Taiga:

The broad band just south of the tundra region of Europe and North America is known as taiga region. The taiga region is in the southern hemisphere, and is poorly developed because of the absence of land mass. This region has evergreen coniferous forests.

Climatic condition of this region is represented by bleak winter and cool summer. Precipitation is of moderate type. The summer lasts from three to six months. Spruce, Firs, Pines and Cedars are the common vegetation.

(iv) Grass lands:

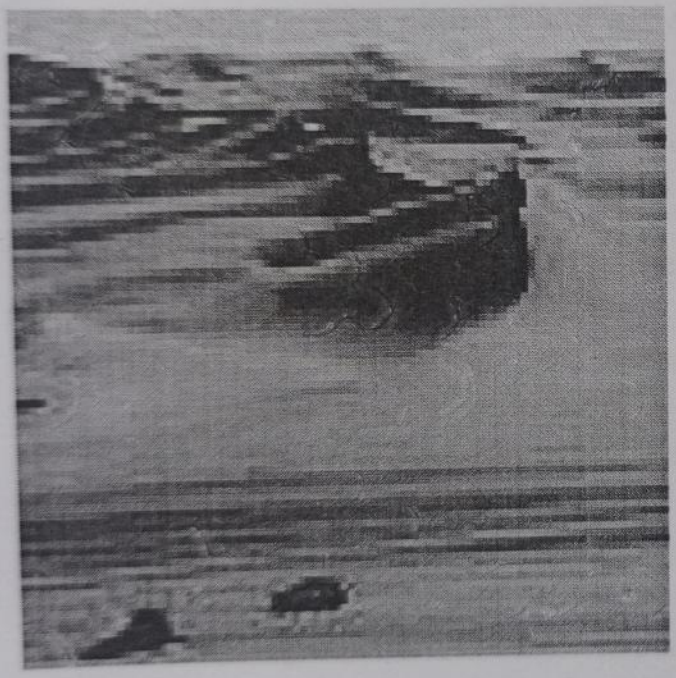
Grassland habitats can be found in many places around the world, both in the temperate and tropical regions and in a variety of climates. These are sometimes called other names, such as **prairies, savannahs, steppes or pampas**, depending on where in the world they are and the sort of climate there. Large areas in both temperate and tropical regions do not support trees but remain covered with heavy growth of grass.



(v) Deserts:

Deserts are the driest places on Earth. Deserts cover at least 20% of the earth. They get fewer than 10 inches (25 centimeters) of rain a year. Deserts occur both in temperate and tropical regions. The plants of the deserts are highly modified to conserve water. The leaves are reduced or absent or modified into thorns. The roots are long and go deep inside the soil. The plants of the deserts are highly modified to conserve water. The leaves are reduced or absent or modified into thorns. The roots are long and go deep inside the soil.

Cacti, Yucca are the dominant plants. Kangaroo, rats, Foxes, Coyotes, many lizards, several snakes and toads are the common vertebrates present in the desert. Deserts may be snowy too.



(vi) Rain forests:

As the name implies, it is an area that gets a lot of rain. The presence of tropical and temperate rainforest on our planet plays a huge role in maintaining the ecological balance and the environment of the whole planet. These forests are the source of oxygen, plants and other species, minerals, etc. Without these equatorial forests survival on the Earth would not be possible. Characteristic vertebrates of these regions are: Monkeys, Sloths, Ant -eaters, Bats, many colorful birds, frogs and salamanders, turtles and snakes.

AQUATIC HABITAT

The aquatic habitat is divided into marine, estuarine and freshwater.

Aquatic habitats are habitats found in water. These areas are usually always covered in water or at least seasonally. Examples include marine, estuaries, and freshwater areas. Aquatic habitats are crucial as about 70% of the earth's surface is covered in water.

Marine Habitat

Marine habitats are areas located in the sea or ocean. Marine habitats are split into the open ocean and the coastal regions. A coastal zone is a region between land and water. Even though these zones only occupy about 7% of the earth's oceans, they are essential because most of the world lives in these zones. The open sea, or the pelagic zone, is the deeper area outside the coastal zone.

The open ocean comprises 99% of the earth's inhabitable spaces and it is divided into the following segments:

- Epipelagic zone: This part is the upper part of the ocean, and enough sunlight characterizes it for photosynthesis. It's around 2-3% of the open sea; beyond this level, it's too dark for photosynthesis. Generally, this zone begins at the ocean's surface till around 600 ft or 200 meters. Algae in the epipelagic area are responsible for about 50% of the oxygen in the earth's atmosphere and create most of the original nutrients for other organisms.
- Mesopelagic zone: This zone is also called the middle part of the ocean or the twilight zone. It begins from the end of the epipelagic area to around 3000 ft or 1000 m deep. Most vertebrate fishes live here and migrate up to the epipelagic zone at night in search of food.
- Bathypelagic zone: This zone can also be referred to as the lower open ocean. This zone begins at the bottom of the mesopelagic area till 13,000 ft or 4000 meters. It's the largest ecosystem on our planet, and there's no sunlight. Some species here have lost the ability to see and use bioluminescence to attract prey. Animals that commonly live here are anglerfishes and bristle mouths.
- Abyssal zone: This zone has almost no life and stretches from the bathypelagic area to the bottom of the ocean floor.

Ocean habitats generally include intertidal, mangroves, mudflats, estuaries, kelp forests, seagrass meadows, coral and oyster reefs, the open ocean, tidewater glaciers, and salt marshes.

- Intertidal environments occur where the shore or land meets the water or usually where

coastal zones occur.

- Mangroves are trees and shrubs that grow near coastal areas; they serve as nursing grounds for marine life.
- Mudflats are muddy parts of water created by silt and mud brought in by the seas and oceans.
- Estuaries are areas with mixtures of fresh and salt water.
- Kelp forests are forests of brown algae; it's home to many species due to the canopy it creates.
- Seagrass meadows consist of underwater plants and serve as an essential food source and habitat for many species.
- Coral reefs contain the most biodiversity out of any aquatic habitat. They support around 25% of all marine life, protect our coastal communities from storms, etc.
- Oyster reefs consist of many oysters. They provide habitats for many organisms, protect coastal areas from erosion, and filter particles in water, improving water quality.

Estuarine Habitat

Lots of coastal habitats can be found where there are estuaries. Estuarine habitats are partly enclosed bodies of water where freshwater from rivers and streams mix with salt water from the ocean, resulting in brackish waters. Brackish waters have higher salinity levels than freshwater but not as high as ocean water. Estuaries attract many migratory organisms, such as birds, and serve as nursery areas for many different organisms. Water quality in estuaries has been affected by runoff contaminated by urban and agricultural development. Structures such as dams that control drainage, electricity, etc., have also affected freshwater flow.

Types **of estuaries**:

- Tectonic estuaries are formed by tectonic or volcanic activity. When plates shift about, they create tectonic estuaries. An example of a tectonic estuary is San Francisco Bay. The San Francisco Bay lies between the Hayward and San Andreas fault lines which interact to cause the downward movement of land or down warping.
- Fjord estuaries occur when glaciers make steep valleys and water fills the area. An example of a fjord estuary is Glacier bay in Alaska. Fjord estuaries are usually cold and narrow; water flows seasonally from rivers and streams.
- Coastal plain estuaries are made when water levels rise and fill river valleys and glacier troughs. The Chesapeake bay was formed when massive glaciers retreated at the end of the last ice age. Afterward, the Atlantic Ocean filled the space with water and created a coastal plain estuary.
- Bar-built estuaries occur when barrier islands or sandbars protect them from the ocean. Barrier islands are long islands parallel to an island's mainland and usually protect it

from storms and erosion. Bar-build estuaries are common along the coast of Texas and Florida, such as the Matagorda bay in Texas.

Freshwater Habitat

Freshwater habitats are places with low or less than 1% salinity content. Plants and animals here are adapted to low salt content and would not be able to survive in areas with high salinity, such as oceans. The different freshwater areas are ponds, lakes, rivers, and wetlands.

Ponds and lakes can differ in size from a few meters to kilometers. Ponds are usually seasonally lasting a few months, while lakes usually last much longer. Both often have limited species diversity because they are not close to rivers and oceans.

They are divided into **three zones**: **littoral, limnetic**, and **profundal**.

- The **littoral zone** is the shallow surface of a lake or pond, making it the warmest part due to the sun's rays. Organisms here include algae, crustaceans, fishes, and other aquatic plants. Turtles, ducks, etc., consume the animals and plants here.
- The **limnetic zone** is the open and well-lit area of a lake or pond with mostly plankton and freshwater fish. Plankton is an essential base of the food chain that allows many organisms to exist.
- The **profundal zone** is colder and denser than the limnetic and littoral zone. The organisms here are heterotrophs who consume other organisms, such as dead plankton, to survive.
- Temperatures in ponds and lakes can differ seasonally. The surface is always warmer than the bottom; during the spring and fall, the top and bottom layers usually mix, circulating oxygen around.

Rivers and streams are water that flows in one direction. The water is cooler in temperature and fresher at the source than at the mouth. Freshwater fish are usually found at the source. Towards the middle, rivers and streams widen, leading to more species being here, such as algae and other aquatic plants. Near the mouth, the water becomes less clear, resulting in less sunlight and less flora and fauna. Organisms near the mouth, such as carp and catfish, require less oxygen.

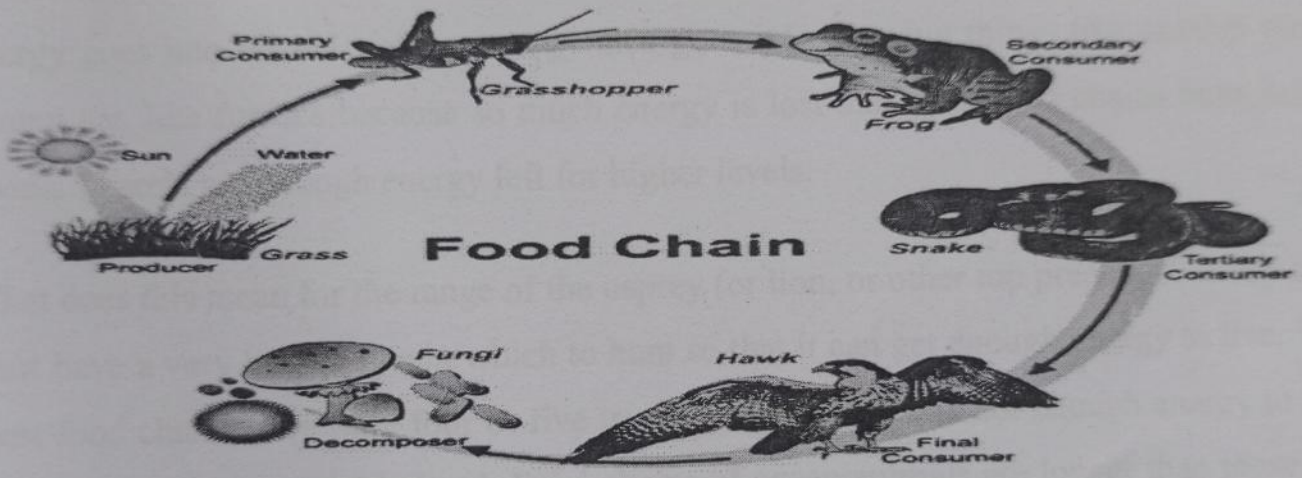
Wetlands are areas made up of marshes, swamps, and bogs. Hydrophytes, or aquatic plants that have adapted to low oxygen levels, dominate here. Hydrophytes include pond lilies, cattails, etc. They have the highest levels of species diversity compared to other ecosystems and are not connected to the oceans, unlike estuaries.

Food Chains and Food Webs

Food chains and food webs are diagrams that represent the feeding relationships from producers to consumers to decomposers. They show who eats whom. In this way, they model how energy and matter move through ecosystems.

Food Chains

A food chain represents a single pathway through which energy and matter flow through an ecosystem. An example is shown in the Figure below



Showing a full-length food chain. Image Credit: Media Wiki.

Food chains are generally simpler than what really happens in nature. Most organisms consume—and are consumed by—more than one species.

EXAMPLES OF FOOD CHAIN

1. TERRESTRIAL FOOD CHAIN
   - Butterfly – small birds – fox
   - Carrots –rabbits – snake – man
   - Corn – chick – snake – man
   - Grass – grasshopper- frog – snake – eagle

2. AQUATIC FOOD CHAIN

- Crayfish – catfish – humans
- Insect – fish – humans
- Plankton – snail – mackerel – shark

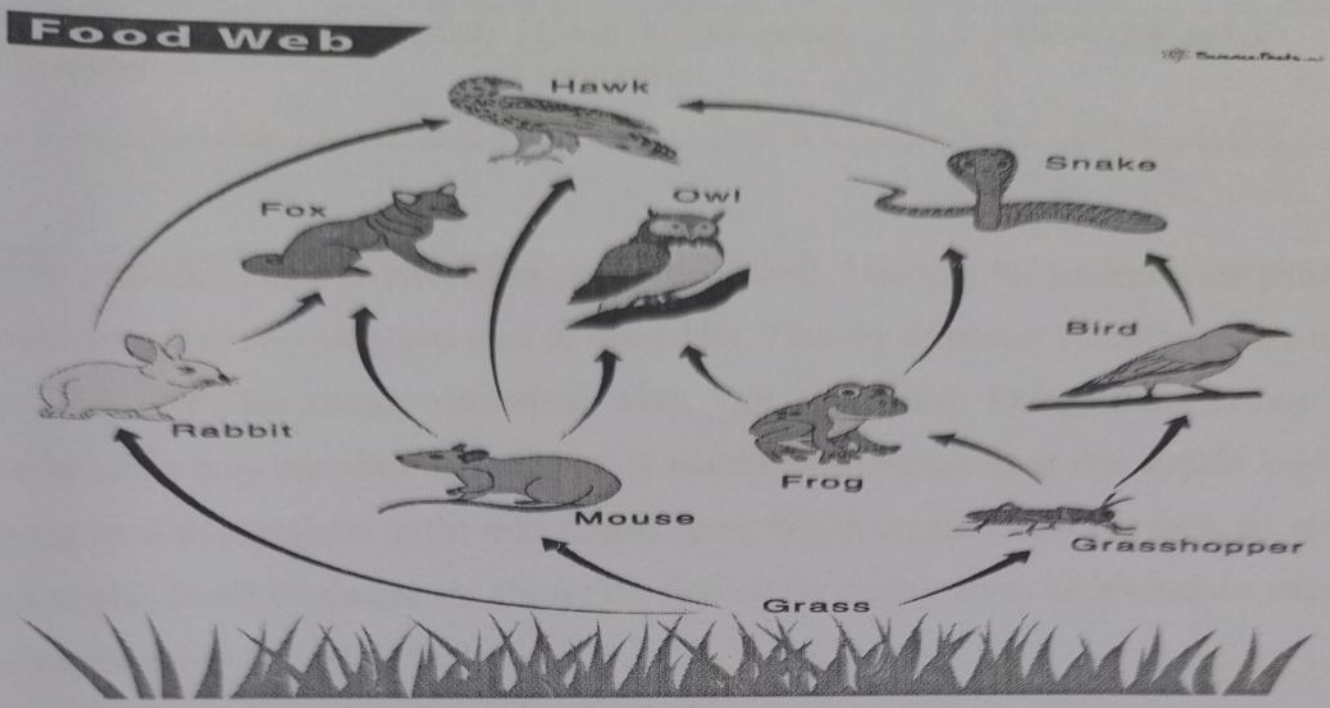
A food chain is a simple diagram that shows one way energy flows through an ecosystem. Producers form the base of all food chains. The consumers that eat producers are called primary consumers. The consumers that eat primary consumers are secondary consumers.

At each level of a food chain, a lot of energy is lost. Only about ten percent of the energy passes to the next level. Where does that energy go? Some energy is given off as heat, some energy goes into animal wastes, energy also goes into growing things that another consumer cannot eat, like fur. It's because so much energy is lost that most food chains have just a few levels. There's not enough energy left for higher levels.

What does this mean for the range of the osprey (or lion, or other top predator)? A top predator must have a very large range in which to hunt so that it can get enough energy to live. Why do most food chains have only four or five trophic levels? There is not enough energy to support organisms in a sixth trophic level. Food chains of ocean animals are longer than those of land based animals because ocean conditions are more stable. Why do organisms at higher trophic levels tend to be larger than those at lower levels? The reason for this is simple: a large fish must be able to eat a small fish, but the small fish does not have to be able to eat the large fish.

Food Webs

A food web represents multiple pathways through which energy and matter flow through an ecosystem. It includes many intersecting food chains. It demonstrates that most organisms eat, and are eaten, by more than one species. An example is shown below



Even food webs are interconnected. All organisms depend on two global food webs. The base of aquatic food webs is phytoplankton and the base of terrestrial food webs is land plants. How are these two webs interconnected? Birds or bears that live on land may eat fish, which connects the two food webs. Humans are an important part of both of these food webs; we are at the top of a food web, since nothing eats us. That means that we are top predators.

Trophic Levels and Energy

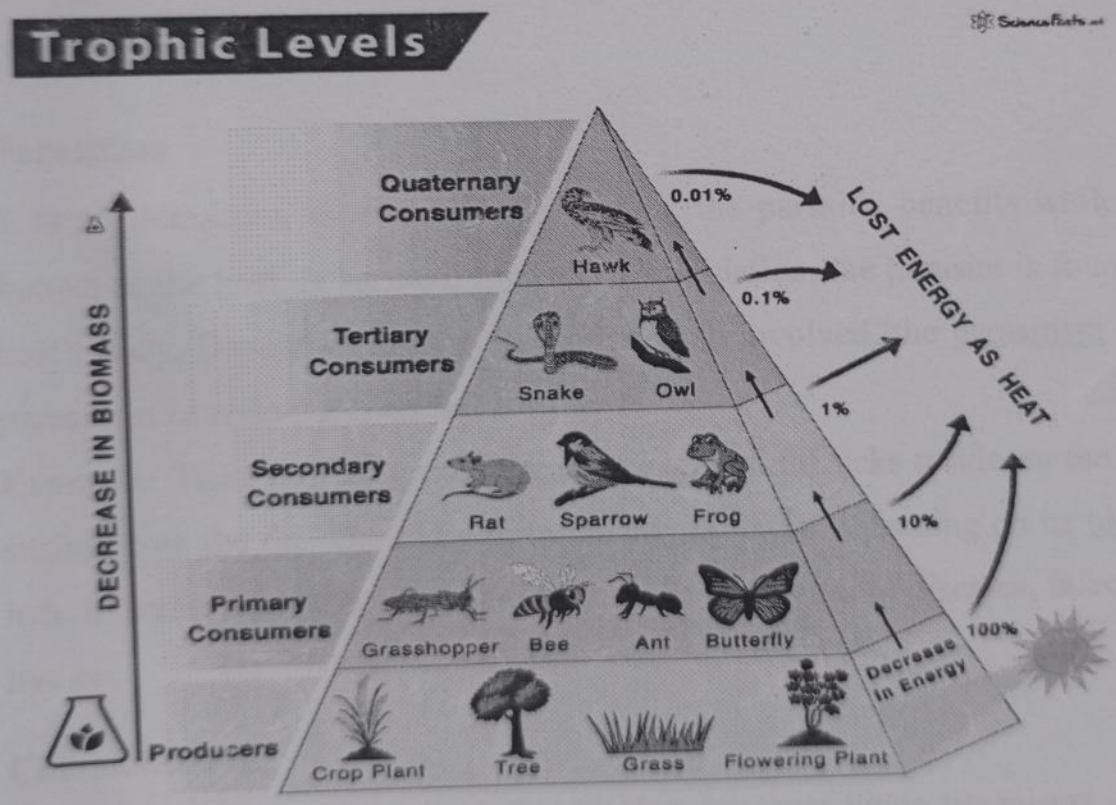
The feeding positions in a food chain or web are called trophic levels. The different trophic levels are defined in the table below. All food chains and webs have at least two or three trophic levels. Generally, there are a maximum of four trophic levels.

Table 1: Trophic Levels

Trophic Level	Where It Gets Food	Example
1st Trophic Level: Producer	Makes its own food	Plants make food
2nd Trophic Level: Primary Consumer	Consumes producers	Mice eat plant seeds
3rd Trophic Level: Secondary Consumer	Consumes primary consumers	Snakes eat mice

4th Trophic Level: Tertiary Consumer	Consumes secondary consumers	Hawks eat snakes

Many consumers feed at more than one trophic level. Humans, for example, are primary consumers when they eat plants such as vegetables. They are secondary consumers when they eat cows. They are tertiary consumers when they eat salmon. Energy flows through an ecosystem in only one direction. Energy is passed from organisms at one trophic level or energy level to organisms in the next trophic level. Which organisms do you think are at the first trophic level? Producers are always the first on the trophic level, herbivores the second, the carnivores



Types of Ecological Interactions

Interaction is necessary for all living being to survive. Like human relationships, ecological interactions which involves animals, plants, microbes etc., also have negative and positive interactions. These biotic interactions may be intra-specific (interactions between same species) or inter-specific (interactions between distinct species).

Predation

Predation is an ecological interaction in which one organism kills and feeds on the other. The killer organism in this interaction is called the predator, and the unfortunate organism that is eaten is called the prey. Example: wild animals like tigers, lions attacking the zebra, deer, cattle, etc.

Competition

Competition is a type of ecological interaction in which two different species fight or compete with each other for the same resource, this form of interaction is termed competition. The animals could compete for resources like food, support, shelter, space, etc. Organisms are compelled to follow this type of ecological interaction for their survival and existence. Such ecological interaction could either lead to the extinction of one of the parties or the extinction of both parties.

Parasitism

It is an interaction in which one organism, the parasite, benefits while the other organism, known as the host, is harmed. In such an association, the parasite is found to live in or on the host's body. Depending on the type of parasite involved, the parasitism may be termed ecto-parasitism or endo-parasitism.

Example: Ticks present on the fur of dogs. Harmful ticks reside on the dog's fur and obtain shelter from the fur. The ticks harm the dog by lavishly feeding on its blood and causing it to itch. In some cases, these ticks are a source of the carrier of diseases, infecting the animals they live on.

Commensalism

It is a one-sided beneficial relationship between two living organisms, where one organism reaps benefits like food or shelter from the other organism without benefiting or harming it. The partners that profit from such a kind of association are commensal, while the latter organism is the host species. A well-known illustration of a commensal is the remora (family Echineidae), a fish that travels in close proximity to sharks and other fish.

Example: Remoras have developed a flat, oval-sucking disc structure on top of their heads

that attach to the bodies of their hosts.

Mutualism

Here, the living beings benefit from each other's company. This is a positive, friendly relationship. A mutualistic interaction comprises two species of organisms that work together, each benefiting from the relationship. A classic example of Mutualism is pollination, as the hungry bee gets its nectar from the flower, and in return, the flower is pollinated by the bee so it can reproduce.

Symbiosis

Symbiosis is a relationship in which both parties are benefited and the organisms live in close contact. A well-known example of symbiosis is seen in lichens. Lichens are made up of algae and fungi. The fungus provides the habitat, while the algae provide food. This way, both organisms benefit from each other . When they continue to interact, they change each other over time. This is called coevolution.

A lichen is a symbiotic association between algae and fungi.

Saprophytism

This is a mode of life exhibited by some fungi and bacteria in which their energy giving and body building requirements are derived from the products of , or the dead remains of , other organisms. Before such remains can be absorbed by the saprophyte, they must be rendered soluble, and the saprophyte is thus often instrumental in initiating the conversion. Therefore it must live in or on the organic material. The conversion process from the complex organic condition to the more simple diffusible condition is generally known as putrefaction or decay. It is a digestive process. Saprophytes are therefore of paramount importance in nature in

maintaining the circulation of materials throughout the living world, since by their putrefactive activity they eventually release into the inorganic environment all the materials taken from it by other living things. They may also be of some economic importance to man in two ways. They may have deleterious effects by causing deterioration in many of his carefully harvested food reserves. On the other hand, they may be put to useful service in synthesizing complex substances valuable to the human race, e.g., organic acids of many kinds, alcohol, vitamins and antibiotics.

The saprophytes must obviously have originated from free – living organisms somewhere along the evolutionary line but connexions are nowhere clear. This is due to the fact that the fungi and bacteria are difficult to drive from any known living things. Some would derive the fungi from the filamentous green and red algae on grounds of structure and reproductive processes and thus would indicate that the saprophytic mode of life is a corollary of the loss of photosynthetic pigments. Others would find the origin of the fungi among the more lowly protozoan animals, in which case the structural and reproductive likenesses to the algae are merely examples of parallel evolution, and the heterotrophic condition inherited. In the past the bacteria have been considered as simple or degenerate fungi. One interpretation tends to separate them from all other classes of living things and to regard them as a third kingdom. In this case, they cannot be linked with any other extant living organisms.

Conclusion

The relationships in nature preserve environments. Many organisms depend on them to survive. Even though some organisms are harmed by these relationships, they are needed to keep the environment in check. The *predator–prey* relationship is one of the biggest contributors to maintaining balance in nature. The predator hunts the prey and keeps its population in check. They maintain the driving force of nature which is its harmony and balance.

Glossary

Host: An organism that provides nutrition for other organisms while itself being harmed

Parasite: An organism that depends on the host for nutrition

Predator: An organism that hunts and eats another organism

Prey: An organism hunted and eaten by a predator